Chemical Engineering Progress

JANUARY 1956

How to test your centrifugal Pumps

NEW HORIZONS

There's SHALE OIL in your future
Where EDUCATION is going
Understanding MERGERS
Planned MANAGEMENT

With

Rotary dryers
Sieve trays • Thesis guide
Congress report • Your California Sojourn

Chemical Engineering Progress

JANUARY, 1956 • Volume 52, No. 1

Publisher
F. J. Van Antwerpen

Editor
J. B. Mellecker

Associate Editors
W. E. Anderson
H. R. Glennon
D. J. Lynde

Editorial Assistants
H. Pittis
E. F. Sheppard

Art Director
Gedeon Takaro
R. M. McCann, *Ass't*

Advertising Manager
L. T. Dupree

What's In This Issue

(Continued on page 5) →

Cover design by Milton Wynne Associates
based on a Union Oil Co. photograph

CEP what's in this issue...

(Continued from page 3)

authors, there may very well be a sizeable industry developed in that area, including even a shale-petrochemicals subdivision.

Advancements in fuel production from oil shale / 22–J

Clyde Berg—Union Oil Company is going ahead with a $5 million pilot retorting and refining project, to take two years. In this article, author Berg (who was chairman of the National Petroleum Council study group which established the comparative economic estimates of shale vs. petroleum oil in 1951) tells of the technical considerations that led up to Union Oil's decision.

Integration in the chemical industry / 26–J

R. B. Schneider—The large number of company mergers which have taken place in the past few years have had a number of basically sound reasons, which have often been coupled with specific advantages for a given occasion. In this article, author Schneider, an official of Empire Trust Company, cites examples of what certain chemical firms accomplished through mergers.

• • •

Liquid film efficiencies in sieve trays / 28–J

A. S. Foss & J. A. Gerster—In this study of sieve trays, performance was found to depend on the total gas throughput rather than its velocity through the perforations. Interfacial area per unit volume of the froth produced continues to increase as the total gas throughput is increased. Froth height and density become correlatible variables describing the physical nature of the froth.

Retention times in a rotary dryer / 35–J

Ford Miskell & W. R. Marshall, Jr.—How long does it take a typical solid particle to travel through a rotary dryer? This is often a critical question, particularly with heat-sensitive materials which could be dried conveniently and cheaply if all particles could be depended upon to travel through the dryer at a specified minimum rate. In this study, the authors dropped radioactive particles in an otherwise conventional feed, and used a geiger counter to determine when they had passed through.

C.E.P.'s annual thesis guide to significant developments in chemical engineering / 39–J

Oftentimes, research performed in the university graduate programs provides data not elsewhere obtainable. This is one reason why C.E.P.'s annual directory of doctoral theses in chemical engineering has come to be so popular among industrial people and others.

New stainless steels avoid use of nickel / 34

Industrial news—As every chemical engineer having much to do with corrosion-resisting equipment knows, nickel has been in not-too-plentiful supply (to meet the unprecedented demand) from time to time. Result: much effort directed toward avoiding its need in stainless compositions. In this C.E.P. resume, several grades now commercially available are described.

Los Angeles Meeting (Subtitle: Your flight from ravages of winter) / 42

Frederick G. Sawyer—A serious look into the program (printed herein) should convince you that the good to be had from the technical sessions will more than compensate for the kidding from the boss as you return thoroughly suntanned from the experience!

Meetings-in-review / 49

Since the last issue of C.E.P. we have been to the Cleveland Nuclear Congress and International Atomic Exposition, and the Philadelphia Chemical Exposition. Here, in brief, is a summary of impressions, plus two pages of specially grouped pictures.

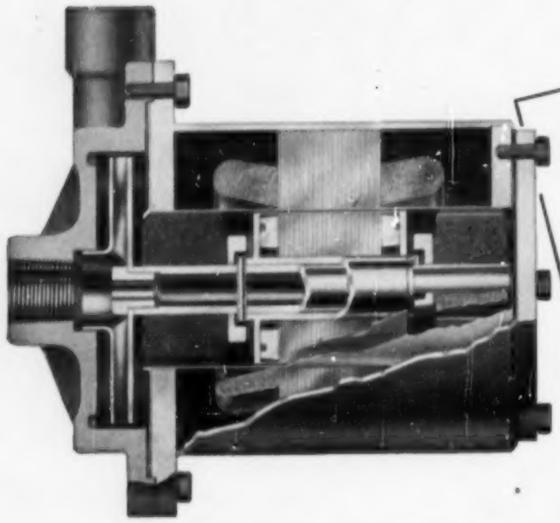
Published monthly by American Institute of Chemical Engineers at 15 North Seventh Street, Philadelphia 6, Pennsylvania, Editorial and Advertising Offices, 25 West 45th Street, New York 36, N. Y. Communications should be sent to the Editor. Statements and opinions in *Chemical Engineering Progress* are those of the contributors, and the American Institute of Chemical Engineers assumes no responsibility for them. Subscriptions: U. S. and possessions, one year $6.00; two years $10.00 (Applies to U. S. and possessions only.) Canada, $6.50; Pan American Union, $7.50; Other Foreign, $8.00. Single Copies of *Chemical Engineering Progress* older than one year cost $1.00 a copy; others are 75 cents. Entered as second class matter December 9, 1946, at the Post Office at Philadelphia, Pennsylvania, under Act of August 24, 1912.

Member of Audit Bureau of Circulations. *Chemical Engineering Progress* is indexed regularly by Engineering Index, Inc.

NEW DESIGN FEATURES OF LEAKPROOF "CANNED" PUMP

extend applications . . .

SLASH PRICE 20-25%!



- **New fabricated construction** is simpler . . . permits mass production techniques. You benefit through lower cost.
- **Construction materials** include titanium, Monel, Carpenter 20, Hastelloy B, Teflon and stainless steels.
- **400% greater bearing area** provides greatly extended service life. Bearings are semi-floating . . . easy to inspect or replace.
- **Series S Chempumps** give leak-proof service at heads to 94 feet, capacities to 50 gpm.

Fifteen years of design and operating experience are built into this new *low-cost* sealless Chempump.

You will benefit directly. You get the cost-saving advantages of mass production techniques. You get a choice of materials of construction that can handle practically any known corrosive. You get a "canned" pump that can't possibly leak, that requires no lubrication, that virtually eliminates maintenance. Oversized, semi-floating bearings give thousands of hours of service under difficult conditions . . . cut-outs provide foolproof motor winding protection for both overcurrent and excessive heat.

The new Series S Chempumps will be available shortly in 1/3 and 3/4 horsepower sizes, with larger units coming. The price is competitive with a quality centrifugal equipped with a mechanical seal. Talk with the Chempump engineering representative in your area about saving through quantity purchases.

- *For complete details, write for Bulletin 1030*

CHEMPUMP CORPORATION
1300 E. Mermaid Lane, Philadelphia 18, Pa.

Chempump

First in the field . . .
process proved


STAYNEW FILTERS
Dollinger makes ALL TYPES of filters as shown on this page, plus special filters for unusual filtration problems. New users of one specific type of Staynew filters often find a second Dollinger filter performs a great, added service in other processes or operations. Perhaps we can serve major or other filtration needs of your plant.
PIPE LINE FILTERS
Model CPH Pipe Line Filter Bulletin 200
Model CVH (Vacuum) Pipe Line Filter Bulletin 200
Model AAPHS (Absorption) Pipe Line Filter Bulletin 200
Model HPH and AHPH (High Pressure) Pipe Line Filter Bulletin 200
LIQUID FILTERS
Model HE (Sump) Liquid Filter Bulletin 330
Model ELS (Pressure) Liquid Filter Bulletin 300
all types of FILTERS for every INDUSTRIAL NEED
AIR INTAKE FILTERS
Model IDR (Ground Level) Air Intake Filter Bulletin 100
Model DS (Silencer) Air Intake Filter Bulletin 100
Model D (Outdoor) Air Intake Filter Bulletin 100
Model C (Indoor) Air Intake Filter Bulletin 100
VENTILATION FILTERS
Electro-Staynew Mist Collector Bulletin 420
Electro-Staynew Precipitator Bulletin 400
Automatic Ventilation Filter Bulletin 500
Dry and Viscous Panel Ventilation Filters Bulletin 600 and 700
DOLLINGER PROTECTOMOTOR STAYNEW FILTERS
DOLLINGER CORPORATION
CENTRE PK ROCHESTER 3, N.Y.
Write, using Bulletin Numbers, for complete information on any of the Staynew filters illustrated. Consult Dollinger engineers on any special filtration problems—no obligation. Dept. 79 Centre Park, Rochester.
LIQUID FILTERS, PIPELINE FILTERS, INTAKE FILTERS, HYDRAULIC FILTERS, ELECTROSTATIC FILTERS, DRY PANEL FILTERS, VISCOUS PANEL FILTERS, LOW PRESSURE FILTERS, HIGH PRESSURE FILTERS, AUTOMATIC VENTILATION FILTERS, NATURAL GAS FILTERS, SPECIAL DESIGN FILTERS, SILENCER FILTERS

LETTERS TO THE EDITOR

A Service Failure

I've recently read your article "Plastics for Chemical Engineering Construction—Polyethylene," in the June, 1955, edition.

I've used some 2,000 ft. of polyethylene pipe, sizes 2" and 3" for hydrochloric acid overhead lines at ambient temperature. It was a serious failure. When the pipe broke open at numerous places and showered passageways with acid, we decided to scrap it after only six months use. By some persistent research, I discovered that this material fails due to a phenomenon known as polyaxial stress which causes the pipe to burst open as if slashed with a razor blade.

I think it very unfair of you not to mention this factor and suggest some correcting remarks in future editions.

L. W. Poll

Waterford, New York

The authors would also feel very unfair if mention of stress cracking of polyethylene in the presence of certain types of environments and under certain stress conditions were not discussed.

We, however, felt that we had sufficiently covered this problem on page 253 of the article under the heading of solvent resistance.

In addition, [Literature Cited 2] (Bockhoff & Neumann, *S.P.E. Journal*, **10**, No. 5, 17 (1954) refers to a rather complete discussion of the phenomenon of stress cracking of polyethylene.

It should be emphasized that the problem of environmental cracking can be almost entirely eliminated through the use of higher molecular-weight polyethylenes or through the discrete use of lower-molecular-weight polyethylenes in dangerous environments.

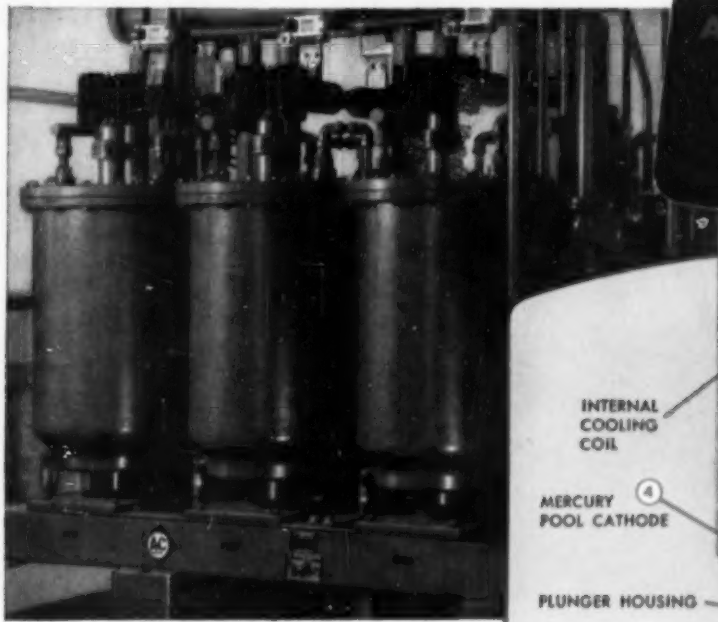
Through honest cooperation between customer and reliable fabricators, this type of problem can be reduced to a rare occurrence.

Frank J. Bockhoff
Richard F. Roth

Cleveland, Ohio
Maple Heights, Ohio

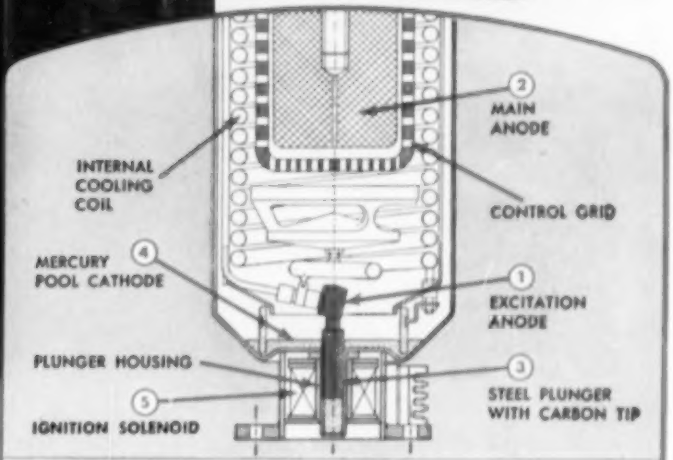
(More Letters on page 18)

Here's the Rectifier That Needs No Delicate Adjustments



This 1000-kw, 6-tube excitron rectifier is typical of units used for heavy-duty service in many industrial plants.

ALLIS-CHALMERS Mercury Arc Rectifiers



LITTLE MAINTENANCE IS NEEDED with Allis-Chalmers excitron-type rectifiers. Excitation of the excitron rectifier is continuous, while other types of rectifiers require re-ignition 60 times a second.

Since it is more difficult to start a rectifier arc than to maintain it, the excitron rectifier is much less likely to lose excitation during operation. Momentary dips in supply voltage which are encountered in many supply systems have no effect on the continuous excitation arc.

Years of operation in hundreds of installations have proved the reliability and ease of operation of Allis-Chalmers mercury arc rectifiers. You can get complete information from your nearby A-C office. Or write Allis-Chalmers, Milwaukee 1, Wis.

A-4581

Unique Plunger Starts Continuous Excitation

The excitron tube has an excitation anode (1) in addition to the main anode (2). With the excitation circuit de-energized, the steel plunger (3) floating in the mercury pool cathode (4) makes positive contact with the excitation anode (as shown).

When the excitation circuit is energized, the ignition solenoid (5) pulls the steel plunger (3) away from the excitation anode (1) and under the mercury pool cathode (4), thus drawing a dc arc and forming the cathode spot, which makes conduction of load current by the tube possible.

If power is interrupted the plunger will float up, contact the excitation anode and automatically re-establish the excitation arc when power is restored.

ALLIS-CHALMERS

S/K apades in industry

THE CASE OF THE PUNGENT FUMES AND THE PROCESS MAN WITH A PLAN

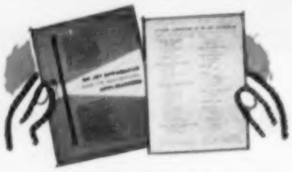
"Gadzooks!" cried Pete the Process Engineer, as he clamped a clothespin on his nose. "I dever sbelled anythig as obdoxious as doze *sulphurous fumes.*"

The *processing units* kept on fuming—and so did the employees who had to endure the odor.

"Do somethig," gasped the Plant Manager. "Those nauseatig fubes and odors are perbeating the whole fagtory. Peoble turn up their dozes at working here . . . "

Pete went into his office and held his head. A jet unit would alleviate odors and pacify his disgruntled boss. A jet unit, but what kind? And what about hoods, ductwork, recirculating system? A *jet* unit? Yes! No fan to corrode or wear out . . .

Pete wrote Schutte and Koerting for a copy of new Bulletin J-1 on "Jet Apparatus and Its Industrial Applications." That told him all he needed to know about the varieties, ranges and characteristics of Jet Apparatus.



Bulletin J-1 pinpointed the data he needed. He located the desired function, the types of jets suitable for such a function, the type most suitable for his particular requirements.

Then he phoned for a specialist—his nearby SK Sales Engineer, who came a-running. And from him, Pete got a specific recommendation.

LICKED THE PROBLEM IN A JIFFY!

The SK Fume Scrubber illustrated is used to absorb sulphurous fumes in Pete's refinery. Rubber lined, the unit resists the corrosive action of the fumes. Discharge is made into a separator and clean air is discharged to atmosphere.

MORAL:
Send for a copy of Bulletin J-1 for your files. And make use of a qualified specialist on jet apparatus —your nearest SK Sales Engineer.

Schutte and Koerting COMPANY
MANUFACTURING ENGINEERS
2245 STATE ROAD, CORNWELLS HEIGHTS, BUCKS COUNTY, PA.

Jet Apparatus • Heat Transfer Equipment
Strainers • Condensers and Vacuum Pumps
Oil Burning Equipment • Rotameters
Flow Indicators • Radiafin Tubes • Valves
Spray Nozzles and Atomizers • Gear Pumps
Desuperheaters

Lapp introduces the "MICROFLO" PULSAFEEDER

A CONTROLLED-VOLUME PUMP FOR PRECISION PUMPING AT MICRO-FLOW RATES

Now, a controlled-volume proportioning pump for laboratory application, pilot plants, and industrial production, where requirements are for pumping of precise volumes at micro-flow rates without risk of leakage or contamination of fluid being pumped. The "Microflo" Pulsafeeder combines the best features of both piston and diaphragm pumps by using a piston for constant volume measuring purposes and a diaphragm to seal the product pumped against leakage or contamination. All liquid handling parts have been selected for their resistance to corrosion. Maximum pumping capacity is 2150 ML. per hour, maximum discharge pressure 1000 psig. Pumping rate of the "Microflo" Pulsafeeder can be manually adjusted while the pump is idle or operating, or if desired, complete operation can be governed by automatic controls.

Lapp

WRITE

for Bulletin 500 which contains complete information and specifications on the new "Microflo" Pulsafeeder. Lapp Insulator Co., Inc., Process Equipment Division, 504 Wilson St., LeRoy, N. Y.

LETTERS TO THE EDITOR

(Continued from page 12)

New Year Bouquets

I would like to congratulate the Institute for the excellent quality of the recent Research Committee meeting on tray efficiency, at North Carolina State College. It is evident that the three schools and the Committee have made substantial progress during the past year.

R. B. Olney
Emeryville, California

I have just had occasion to read the October issue of Chemical Engineering Progress. This special nuclear issue is certainly one of the best put out to date. I can certainly appreciate the time and effort which it represents. My sincere congratulations for the excellent editorial and publishing job. I can say, without reservation, that CEP has definitely reached new heights of showmanship and coverage since you became editor and Van took over as publisher.

Charles H. Prien
Denver, Colorado

noted and quoted

Four Engineering Fables

Fable 1—Ethyl Assinate

Once upon a time there was a Dulle Chemical Company and a Sharp Chemical Company. Dulle was proud of its engineering department. Its cost of engineering, expressed as a per cent of project cost, was very low. Sharp was worried about its engineering department. Its cost of engineering was very high.

One day the two companies, simultaneously and independently, undertook the design and construction of plants to produce ethyl assinate. They used the same process and had the same design basis of capacity, etc.

Dulle Engineering expended $300,000 for engineering on the project which had a total cost of $5,000,000. Its cost of engineering, therefore, was 6% of the project.

Sharp Engineering expended $400,000 for engineering, $100,000 of which was involved with the study of economic alternates to reduce capital requirements. As a result, the total cost of its project was only $4,000,000. Its cost of engineering, however, was 10% of the project.

And so, Dulle continued to be proud of its engineering department and

(Continued on page 20)

noted and quoted

(*Continued from page* 18)

Sharp continued to be worried about its engineering department.

Moral—Engineering is a means to a variable end.

Fable 2—Insidious Chloride

Once upon a time, Dulle Chemical and Sharp Chemical, simultaneously and independently, undertook the design and construction of plants to produce insidious chloride. They used the same process and the same design basis of capacity, etc.

Dulle Engineering prepared equipment sketches, piping flow sheets, wiring diagrams, and building out line plans. Sharp Engineering prepared equipment specifications and drawings, piping specifications and detail drawings, electrical specifications, and detailed wiring drawings, architectural specifications and detail plans, and developed other details required to complete the design of the plant.

The two plants were built side by side. Sharp's plant progressed smoothly and efficiently because of the completeness of the design. On the other hand, the construction of Dulle's plant was quite inefficient because of the lack of design details. However, when the plants were completed, they were identical.

Dulle's plant cost $5,000,000. Since its cost of engineering was $300,000, it represented 6% of the project cost. Sharp's plant cost $4,000,000. Since its cost of engineering was $400,000, it represented 10% of the project cost.

And so, Dulle continued to be proud of its engineering department and Sharp continued to be worried about its engineering department.

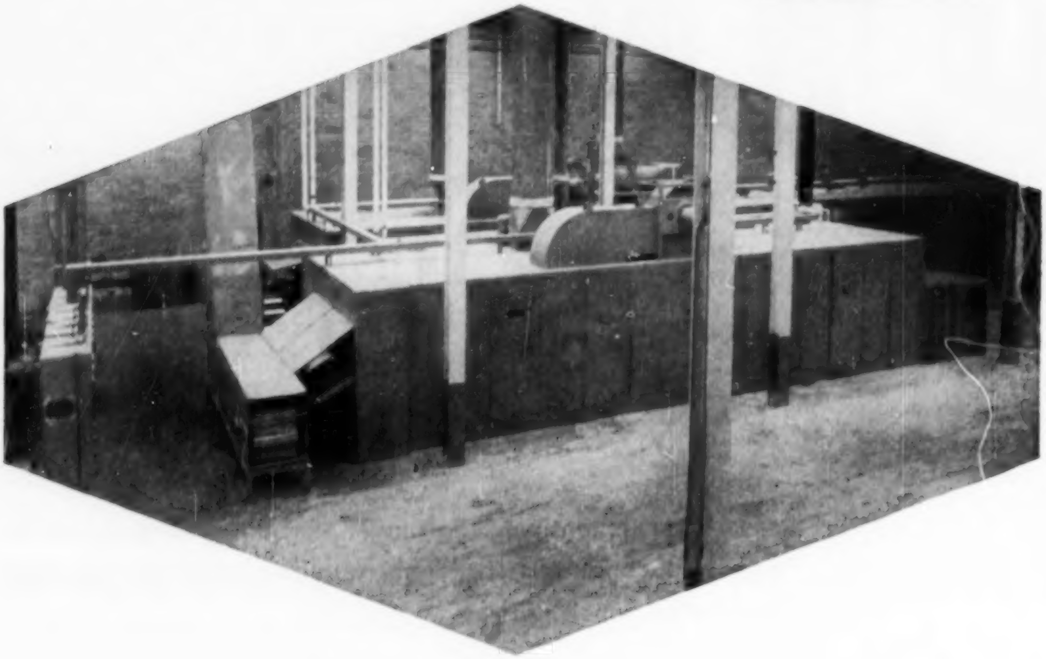
Moral—Engineering is a variable means to an end.

Fable 3—Apathetic Bromide

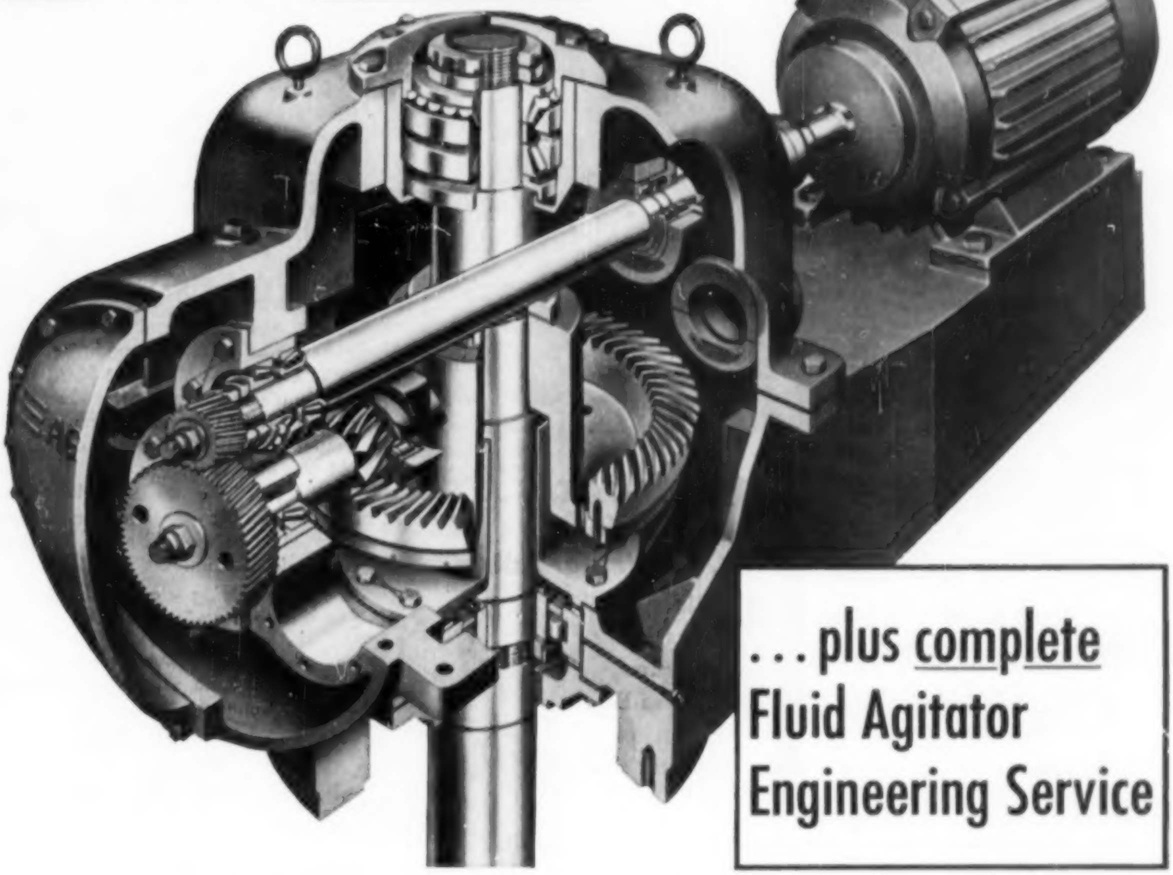
Once upon a time, Dulle Chemical and Sharp Chemical, simultaneously and independently, undertook the design and construction of plants to produce apathetic bromide. They used the same process and the same design basis of capacity, etc.

The process used was developed by T.V.A. It involved the liquid phase reaction between apatheticamide vapor and bromine crystals. Since a considerable quantity of inert gas was evolved in the reaction, and since apathetic bromide is somewhat volatile, the la-

(*Continued on page* 24)



<u>only</u> PHILADELPHIA gives you <u>all</u> these <u>features</u>



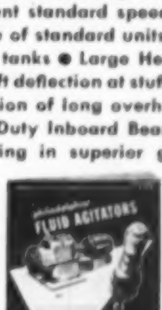
. . . plus <u>complete</u> Fluid Agitator Engineering Service

Now, for the first time one manufacturer is able to offer a completely integrated, "packaged" fluid agitator service. No other manufacturer controls, within its own organization, such extensive and specialized designing, engineering, manufacturing, assembling, testing, and field servicing facilities devoted exclusively to fluid agitator production. Philadelphia Gear Works manufactures impellers, shafts, drive supports, all gears, and reducer housings. Only Phillie Gear can offer you the complete solution of your fluid agitator problems —through one centrally-controlled, thoroughly responsible source.

Our engineers are familiar with the requirements of all types of process mixing and fluid agitation applications.

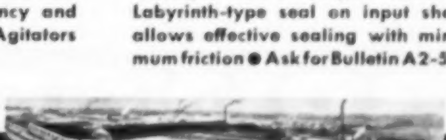
Philadelphia Gear Works products have "measured up" through 63 years of industrial leadership. Compare the new Philadelphia Fluid Agitators for economy, efficiency and quality. See for yourself why Philadelphia Fluid Agitators are your very best investment.

COMPARE THESE FEATURES: Exclusive Philadelphia Low Head Room Design—maximum bearing span with minimum headroom ● Helical Change Gear Set, within housing, allows for ready selection of up to 14 different standard speeds ● Heavy Duty Thrust Bearings permit use of standard units for conditions of high pressure in closed tanks ● Large Heavy Duty Output Shafting results in less shaft deflection at stuffing box or mechanical seal, steady operation of long overhung agitator shafts ● Philadelphia Heavy Duty Inboard Bearing Support provides extra rigidity resulting in superior gear performance and life ● Spiral Bevel Gears of Hardened Steel, accurately lapped for long and quiet operation ● Field-proven Philadelphia Dry-Well Construction prevents oil leakage down output shaft ● Labyrinth-type seal on input shaft allows effective sealing with minimum friction ● Ask for Bulletin A2-55.



PHILADELPHIA GEAR WORKS, INC.

ERIE AVE. & G ST., PHILADELPHIA 34, PA.
NEW YORK • PITTSBURGH • CHICAGO • HOUSTON • LYNCHBURG, VA.
BALTIMORE • CLEVELAND
Virginia Gear & Machine Corp. • Lynchburg, Va.



Industrial Gears & Speed Reducers

LimiTorque Valve Controls

Established 1892

noted and quoted

(*Continued from page* 20)

boratory equipment included a cold trap cooled with liquid air. The yield was 95%.

Dulle Engineering designed the plant to equal the T.V.A. yield. Included was a large refrigeration unit to recover the last trace of product from the off-gas. Sharp Engineering designed the plant to give the maximum return on investment. It did not involve refrigeration but did not recover the last trace of product.

Dulle's plant cost $5,000,000. The manufacturing cost of product was $0.10/lb. and the annual return on investment was 4%. The operating yield was 95%. Sharp's plant cost $4,000,000. The manufacturing cost of product was $0.08/lb., and the annual return on investment was 12%. But the operating yield was only 90%.

And so, Dulle continued to be proud of its engineering department and Sharp continued to be worried about its engineering department.

Moral—Engineering is a variable means to a variable end.

Fable 4—Reverie

Once upon a time there *was* a Dulle Chemical Company.

Moral—Engineering is a means to an end.

R. L. Bauer, chief engineer
Mead Johnson & Company
Evansville, Indiana

Lavish Use of Natural Resources Deplored

. . . We can be certain . . . that the future will not always be distant and that a natural resource, once lost, will cost more to regain than it would cost to preserve. Can we be sure that the resources we use so lavishly today may not be essential for mankind some day? . . .

Almost invariably, when a pollution problem is under consideration, the engineer's approach is to compare the total salaries paid by the industry with the income derived by the fishing interests which may be endangered. This comparison always favors industry but is it not specious and false reasoning to say that because industry is wealthy the fisherman should be willing to sacrifice his livelihood? Will not the factory worker ultimately suffer for each natural resource lost?

Bostwick H. Ketchum
at Diamond Jubilee Semi-Annual meeting, A.S.M.E.

(*Marginal Notes on page* 28)

MARGINAL NOTES

Principles of Engineering Thermodynamics, 2 ed. P. J. Kiefer, G. F. Kinney, and M. C. Stuart, John Wiley & Sons, Inc., New York, Chapman and Hall, Ltd., London (1954).

Reviewed by Wayne C. Edmister, California Research Corporation, Richmond, California.

This book is a comprehensive and well-written text. As in the first edition (1930), the authors have divided the book into parts dealing with the following: energy, properties of fluids, and engineering applications.

The chapter on combustion includes a treatment of combustion reaction equilibria.

Power generation is covered in two chapters, one dealing with cycles using condensing fluids and one with cycles using noncondensing fluids. There is also a good chapter on heat-pump and refrigeration cycles.

The chapter on flow of compressible fluids deals with three types of flow, e.g., through nozzles, diffusers, and pipes. A convenient chart for calculations of adiabatic flow of ideal gases is included and applied.

Thermodynamics topics not included in this book include: properties of complex mixtures, phase equilibria, equilibria of other than combustion reactions, irreversible thermodynamics, and statistical thermodynamics. These omissions do not detract from the value of the book, however, as one book cannot cover everything, and these topics can logically be left to the authors of chemical or chemical engineering thermodynamics texts.

BOOKS RECEIVED

Soil Warming by Electricity. R. H. Coombes. Philosophical Library, New York (1955), 116 pages, $4.75.

Aluminum Paint and Powder. J. D. Edwards and R. I. Wray. Reinhold Publishing Corp., New York (1955), 219 pages, $4.50.

Basic Lubrication Practice. A. F. Brewer. Reinhold Publishing Corp., New York (1955), 286 pages, $6.75.

Brand of The Tartan, The 3M Story. Virginia Huck, Appleton-Century-Crofts, Inc., New York (1955), 260 pages, $3.50.

Catalysis. Vol. 3. Ed. P. H. Emmett. Reinhold Publishing Corporation, New York (1955), 504 pages, $12.00. (Hydrogenation and Dehydrogenation.)

Chemical Engineering in Practice. Ed. J. I. Harper. Reinhold Publishing Corporation, New York (1954), 140 pages, $3.00.

Plastic Tooling. M. W. Riley. Reinhold Publishing Corp., New York (1955), 123 pages, $2.50.

Fisher/Tag Manual for Inspectors of Petroleum. Fisher Scientific (1954), 218 pages.

CEP trends / CUE FOR 1956: PROSPERITY AND OPTIMISM

There has not been a year in a long time that has closed with more widespread prosperity or more optimism on the part of business leaders than 1955.

To those whose memories go back to the boom days of 1929 and the collapse of the 1930's such universal confidence is almost frightening. But the pessimists have been unable to find any cogent reasons for their fears beyond the general theory that when things are very good they are likely to turn around the other way. There is no sound reason for believing that prosperity always carries within itself the lurking germs of a depression.

Unreasonable extremes and unbridled speculation are of course storm breeders. Business did *not* collapse in 1929 because it was making more goods than people wanted to buy: the crash in 1929 was primarily a stock-market and credit crash which carried the business world down with it. The production being absorbed in all fields today is many times what it was then.

How Firm a Foundation

Today's booming prosperity rests in part on the highest wage scale in the history of the country, a scale that seems certain to trend steadily higher. It also rests on an apparently firm credit foundation as far as industry goes. The chemical industry, which has had a dramatic expansion over the past five years, accomplished this with a comparatively moderate debt, most of it on a long-term basis at low interest rates.

Recently polled chemical leaders expect to continue their plant expansion in 1956 at a rate as high or higher than in 1955. Most of the big firms now believe that they can continue this rate of expansion, at least, for the next year or two without recourse to outside borrowing. A huge cash inflow resulting from depreciation charges, fast amortization and surplus earnings makes this possible.

The Department of Commerce recently estimated that spending by business as a whole for new plants will increase in 1956. Other private surveys hold that it will probably continue to rise for several more years. As the review of the Machinery and Allied Products Institute points out, industry as a whole should be able to generate 90 to 95% of the money for new capital expenditures from internal sources.

Billions for Expansion

In 1955 the chemical industry spent around $1 billion on new plants and facilities, according to the Manufacturing Chemists Association, making the fifth consecutive year in which this sum has been spent by the industry. Sales for the industry for the year 1955 reached an all time high of $23 billion, up 17½% over the 1954 sales of $19.5 billion, and some industry leaders believe their sales will be at a materially higher rate in 1956.

Taking a look at some of the diverse industries which are customers for chemicals, there are few serious clouds in sight. Secretary of Commerce Sinclair Weeks in a year-end statement said he expects industry as a whole to operate around peak levels during the first half of this year. He forecasts chemical sales for this period at $12 billion.

In some quarters there are doubts about the continued peak production of the motor industry, a major chemical customer. George Romney, president of American Motors Corp., for example, thinks the industry will have a dip of about 15% to 6,800,000 cars in 1956 from 8,000,000 cars in 1955. If this should occur, it would hardly be a catastrophe, but not all motor makers share this view. As for Secretary Weeks, his department forecasts an output of 4,250,000 cars in the first half of this year.

Home building, becoming increasingly important in chemical purchases, both directly and indirectly, seems slated for a slight letdown. The Commerce Department estimates that about 1,200,000 houses will be started in 1956, a decline of about 100,000 from the 1955 rate, but again, if the setback is no worse than this, it will be nothing to worry about. Total construction expenditures for 1956, on the other hand, are expected to show a gain to $44 billion from $42 billion in 1955.

Other chemical consuming industries, such as rubber, pulp and paper-board and plywood, are expected to show gains in production and sales in the first half of this year.

The steel industry, which operated at capacity levels through last year, can hardly produce much more this year, but the industry has major expansion plans under way.

One Small Cloud

As for the consumer, there is no particular indication that he will pull in his horns, particularly if employment continues steady and wage levels hold. The only cloud in the credit situation exists over this area—the area of consumer installment buying. Consumer income is running at a record annual level of around $310 billion and is still rising. This is, of course, the credit base. Although there is no doubt that a large proportion of the population is in debt for homes and goods, these loans are being steadily liquidated. Some people are perhaps overextended and a decline in employment would hurt, but there seems no reason to believe that this is true of the majority of the American public.

CEP

opinion and comment

. . . AND THE FUTURE SHALL BE AT LEAST INTERESTING

This is an unusual issue of C.E.P. and its effect may be realized more fully through some discussion on this page.

We are privileged to carry this month the writings of individuals who have worked hard and long to bring before members of the chemical engineering profession certain issues that they believe should be faced with more initiative and imagination than seems to have been shown in the past. We are referring in particular to two of the five papers bonded together this month in a special section, inasmuch as these two might be classed as philosophical, in a practical sort of way.

Both of these contributions have to do with men: Elgin on their early or basic training for the profession, and Smiddy on their later training and assignment into roles which will elicit from them a maximum contribution.

Both Elgin and Smiddy have written in the role of reformers, in that they call for an end to the placing of major dependence on the hit-or-miss approach to the attainment of needed quality and quantity of properly trained men for professional and managerial roles, respectively. As reformers, they are proposing concepts and actions that many will view askance if not with alarm, if for no other reason than simply because they will entail doing some things differently than we have in the past. Yet, in a field as heterogeneous and complex as ours it is difficult to be certain, even if one tries very hard, of exactly what *is* radical, since the chances are it has already been done somewhere.

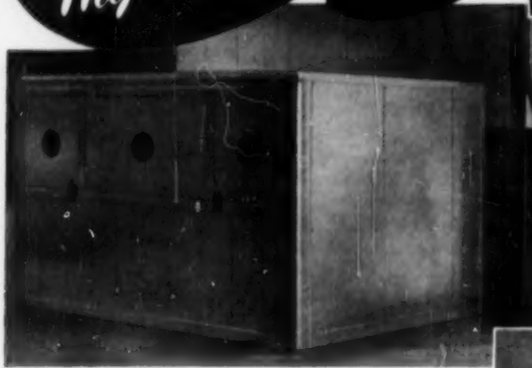
Take Elgin's prediction that industry will assume a major role in the training of the engineer in the applied, or practical phase of his subject. Radical? Not if one looks closely into the comments of Smiddy on the subject of education-by-industry, where one learns that General Electric, for example, has already made major progress in that direction. Other such parallelisms are found between the two writers, on other aspects of the subject.

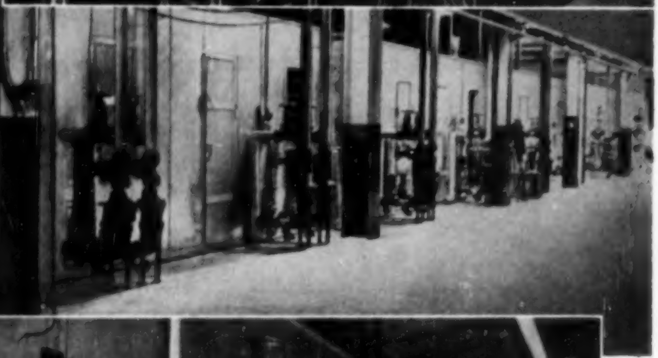
In considering the interrelationships between the two articles, it is important to consider that one of these men is an educator, the other an industrialist. Both are renowned in their respective fields. They wrote independently without access to the other's thoughts, either unwritten or written. Without, therefore, having influenced each other, it is interesting to see to what degree they do coincide—philosophically, of course.

Whatever your own stand—whether you are a staunch traditionalist who would like to see engineering become a more concise science of processes and tools (to quote a phrase coined, as far as we know, by Van Antwerpen), or believe it will become a science of transfer rates and other such phenomena—we do hope that you find the special articles of this first-of-the-year issue challenging to your own imagination—which is, by inference, one way of wishing you off to a "happy new year."

J.B.M.

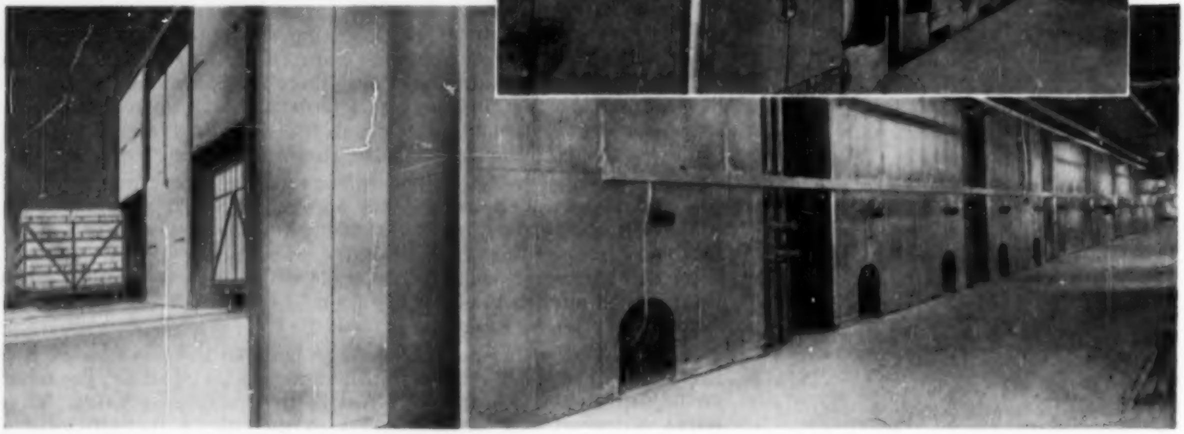
Keep Ahead in '56... With "NATIONAL" High-Speed Dryers





CONVEYOR and TRUCK TYPES

Designed with many exclusive features assuring consistently greater production, lower operating costs and improved product. Illustrated above: Two large Conveyor Dryer installations. At right, and below: Two high-capacity Truck Dryer installations.

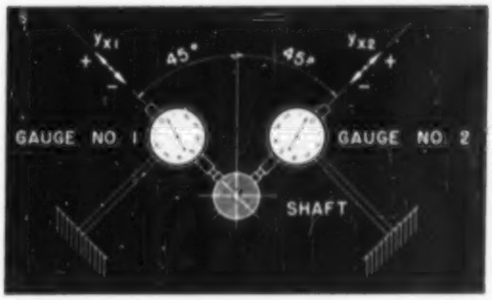


"P-4" CONSTRUCTION provides a precision-built, prefabricated, truss-type structure, for greater strength, rigidity and durability. IMPROVED HOUSING PANELS are larger and stronger, with 4" insulation to reduce heat loss to the minimum. OTHER ADVANTAGES include a superior Air Distribution and Control System; Super-Power Fans; Continuous Hopper Feeds; and Automatic Leveler to conveyor belt. *Write for complete information.*

THE NATIONAL DRYING MACHINERY CO.
LEHIGH AVENUE and HANCOCK STREET
PHILADELPHIA 33, PENNA.

New England Agent: JONES & HUNT INC., Gloucester, Mass.
Cable Address: "NADRYMA"—W. U. Code

Fig. 3. Mounting of dial gauges on pump shaft (viewed from coupling end of pump).



MECHANICAL DESIGN OF CENTRIFUGAL PUMPS FROM SHAFT DEFLECTION MEASUREMENTS

D. S. Ullock, J. A. Reynolds, and T. W. Hudson

Carbide and Carbon Chemicals Company
South Charleston, West Virginia

The significance of knowing the unbalanced hydraulic radial load developed in a centrifugal pump casing and the resulting shaft deflection and bearing lives has been demonstrated (*3*). In volute-type pumps, it reaches a maximum value at or near closed discharge. Shaft deflection from unbalanced radial load is the important deflection in contrast to that present from shaft whip and out-of-roundness and bearing looseness. The latter can be kept within reasonable limits by good shop practices. A knowledge of the unbalanced radial load allows us to determine whether it is too large for the shaft and the bearings in the pump. If it is too large, the shaft is deflected excessively and wear will take place inside the pump at points of close clearance, such as the leakage joints. Also, the packing cannot prevent excessive leakage, and scoring of the shaft or shaft sleeve may take place when the operator tightens the packing to reduce the leakage rate. If the loads are too large for the bearings, they will fail prematurely and require frequent replacements.

Methods are available for estimating the experimental constants in the equation for the unbalanced radial load developed in a centrifugal pump, but the experimental constants applicable to different centrifugal pumps may vary widely. If the user of a centrifugal pump finds that he must replace scored shafts or shaft sleeves or bearings frequently, the pump may be of weak mechanical design. It is possible for him to check its design by obtaining a measurement of shaft deflection with dial gauges or other suitable devices and calculate the unbalanced radial load. With this information, the user can determine (1) whether a larger shaft and/or bearings can be installed, (2) whether the pump should be operated over a limited capacity range, (3) whether the pump should be replaced with one of adequate mechanical design.

Failure of the bearings, especially the thrust bearing, may result from high axial loads. In order to estimate the axial loads on the thrust bearing, it is necessary to calculate or measure the average pressure in the volute of the casing, at the wearing rings or leakage joints, and at the bottom of the stuffing box (or at the hub on the back of the impeller). Knowing the impeller dimensions and the pressures, the net axial thrust can be calculated.

It is the purpose of this paper to show how the shaft-deflection measurements can be made and what other factors may cause shaft deflections, such as impeller weight and elastic deformation in the bearings. Equations will be presented relating unbalanced radial load and impeller weight with bearing loads, elastic deformation in bearings, and shaft deflection. An equation is developed relating the measured deflection values with the unbalanced radial load developed in the pump casing and the deformation in the bearings caused by this load. In addition, a summary is presented of the calculated values for radial and axial loads on the bearings and the values for bearing lives.

Experimental Method

The pump used for the measurement of shaft deflection was a horizontal single-stage, end-suction centrifugal with semi-open, overhung impeller in a volute casing. Its impeller-shaft-bearing assembly is equivalent to that shown in Figure 1. It has a cutwater radius to impeller radius ratio of 1.10 and a maximum volute area of 21.0 sq.in. This ratio and volute area are of interest to pump designers and to those who want to calculate the pressures in the casings. This pump has a vertical wear ring or leakage joint with an axial clearance. The shaft can deflect a considerable distance before the impeller will rub against the casing walls. If the shaft is too light in volute-type pumps with a horizontal leakage joint, the radial clearance may be too small for the deflection present, and the impeller will ride on the casing wear ring when the pump is operated at reduced capacities. If this is the case and if the deflections are to be measured over the capacity range for the pump, the leakage joint clearance must be enlarged so that the shaft may deflect freely. The pump's head vs. capacity curve is shown in Figure 2. Shaft deflection measurements were made with two dial gauges arranged as shown in Figure 3 and were located on the exposed shaft 5.5 in. from the impeller centerline. These gauges were graduated to 0.0001 in. and one complete revolution of the pointer represents a shaft deflection of 0.0100 inch. For convenience of mounting, it is preferable to have gauges with movements that travel up to twenty-five revolutions. The gauges are mounted on the shaft such that the needle is approximately at the mid-point of its travel.

In order to make satisfactory measurements, the pump must be in good mechanical condition, *i.e.*, the bearings must be properly installed on the shaft and the assembly properly mounted in the bearing housing. The shaft must be straight so that runout or out-of-roundness of the shaft at the impeller centerline will be low, preferably not greater than 0.001 in. Although not particularly important for a vertical leakage joint, the metal surfaces of a horizontal leakage joint should be concentric with the centerline of the shaft and should have approximately the same tolerance as the shaft.

Erratic gauge readings are prevented when the shaft is smooth and lubricated at the point of measurement. In addition, the bracket arms supporting the gauges should be mounted on the pump frame as close as possible to the point of measurement. Wear of the gauge spindle and sliding of the spindle off the shaft can be prevented by the use of a ball attachment or miniature bearing foot attached to the spindle. Ball attachments were used for

Tables 1 and 2, complete development of Equations 1-88, and Notation are on file (Document 4775) with A.D.I. Auxiliary Publications Project, Library of Congress, Washington, D. C. These data are obtainable by remitting $1.25 for photoprints and $1.25 for microfilm.

making the measurements reported in this paper.

TEST PROCEDURE AND MEASUREMENTS

The gauges were mounted on the shaft. The shaft was rotated by hand and the maximum and minimum readings recorded for each gauge. The motor was turned on and the maximum and minimum readings of the vibrating gauge pointer were recorded as dry-run readings. The pump casing did not have a drain outlet. As much water as possible was removed from the pump casing by revolving the impeller with the motor. If the pump casing was completely empty of water, the dry-run readings would represent the datum for shaft deflection measurements (shaft bending and bearing deformation) caused by unbalanced radial load. Because the gauges are installed with the impeller mounted on the shaft, the effect of impeller weight has been eliminated. If the bearings have been properly installed, looseness present in the bearings should not be important. A comparison of the static readings (by hand) at the start of the test with those at the end of the test will indicate whether the gauges have slipped and whether wear has taken place where the spindle of the gauge rides on the shaft. Some idea of looseness present in the bearings can be detected by applying a small force to the shaft at the coupling end to offset the weight of the impeller.

The pump was then ready for measuring deflections at various capacities. The test was started with the pump operating near its maximum capacity. The maximum and minimum gauge readings were recorded for seven points on the pump's capacity curve from zero to the maximum capacity. About four sets of measurements were made at most of the seven points. The pump was then emptied of water, as described above, and the dry-run and hand readings were taken again. Results of these measurements and the average readings for each gauge are presented in Table 1. The average readings from each gauge are averaged for each capacity and summarized in Table 2. The plus and minus signs in Tables 1 and 2 (on file with A.D.I.) refer to the position of the dial indicator's pointer. As shown in Figure 3, when the pointer moves to the left of the gauge's zero mark, the reading is negative, and the shaft has moved away from the dial gauge. When the pointer moves to the right of the gauge's zero mark, the reading is positive, and the shaft has moved toward the dial gauge.

INTERPRETATION OF THE EXPERIMENTAL MEASUREMENTS

Inspection of the hand readings in Table 2 indicates that at the end of the test the shaft had not returned to its original position. This may be due to a combination of at least three factors: (1) possible wear at the ball attachments, (2) looseness in the bearing mountings, and (3) inelasticity of the shaft for small loads. Shaft deflection from unbalanced radial load should be close to zero when this pump is operated at or near 1,500 gal./min., its point of maximum efficiency. The gauge readings for hand rotation and when operating around 1,500 gal./min. are nearly the same. However, because the unbalanced radial load, although a minimum, is not necessarily zero at the point of maximum efficiency, these readings do not need to be the same. In addition, it should be noted that the shaft movement or the unbalanced radial load is rapidly changing direction as the point of maximum efficiency is passed. The gauge readings indicate that this is happening.

The dry-run readings at the start and at the end of the measurements are approximately the same, but they are radically different from the hand readings and do not compare with the deflection data near 1,500 gal./min as the hand-run data did. Because the pump casing could not be drained satisfactorily, it is believed that some of the water remained in the casing and interfered with what would have been the datum measurements. Therefore, it was decided that the dry-run readings could not be used.

The dial gauge readings were plotted for each gauge as shown on Figure 4 and a curve drawn through the points. If the gauge reading for each gauge is read from the curve at 1,500 gal./min., the point of maximum efficiency, it may be used as the approximate datum readings for the gauges, and it would be approximately what the dry-run readings should have been. This datum reading for each gauge is subtracted from the gauge readings, the resulting values represent approximately the actual shaft deflections as measured by each gauge. From these values, the deflection of the shaft and the direction of the deflection can be calculated by treating these values as vector quantities. The shaft deflection values for each gauge, the resulting shaft deflection, Z_x, at the point of measurement and its direction are presented in Table 3. The amount of unbalanced radial load at the impeller center line and its direction is shown in Figure 5 for seven capacities. The methods for obtaining the values for unbalanced radial load will be shown later.

Evaluation of Unbalanced Radial Load, Constants, Shaft Deflection

The test procedure above and the equations on page 5-J allow including all factors known to be important such that the unbalanced radial load may be calculated with a reasonable degree of accuracy. By determining the values for the radial load constants, a check can be made of the usefulness and the reliability of the available empirical formulas for calculating unbalanced radial load. When these constants are known for a particular pump design, it is possible to estimate the unbalanced radial load, bearing load, and shaft deflection for other impeller dimensions and operating conditions.

APPROXIMATE VALUES FOR RADIAL LOAD

The pump user may not be particularly interested in radial load constants and their uses. His primary interest should be in knowing the adequacy of the mechanical design for his pump, in which case he would be interested only in the approximate values for radial load at the impeller and the bearings, and the resulting shaft deflection and bearing lives.

Where the interest is limited and where approximate values will be satisfactory, the following procedure for evaluating radial load can be followed: The experimental values for shaft deflection, Z_x, in Table 3, can be substituted in Equation (*6B*)† and this equation is solved for W which is W_r. Substituting the values for W_r in Equation (6)† gives the shaft deflection at the impeller centerline. When elastic deformation in the bearings is not taken into account, the values obtained by this procedure for radial load, W_r, and the shaft deflection, Y max., will be larger than the actual values. For example, the actual value at zero capacity for W_r is 335 lb. and for Z max. is 0.0150 in. (Table 4) compared with 410 lb. for W_r (from Equation (*6B*)) and 0.0165 in. for Y max. (from Equation (6)), when bearing deformation is not taken into consideration. These higher values, although not exact, establish the magnitude of the radial load and shaft deflection and that is of primary importance to the pump user.

ACTUAL VALUE FOR RADIAL LOAD

When more accurate values for unbalanced radial load and radial load constants are desired, the following procedure would have to be followed. The experimental values for shaft deflection Z_x in Table 3 are substituted in Equation (*8B*)‡ and the resulting values for the unbalanced radial load, W_r, are determined by trial-and-error calculation. These values for W_r are substituted in Equation (1) and this equation is solved for K, the unbalanced radial load constant, which varies with the pump's capacity. Substituting the values for K in Equation (*1A*) and solving for k, gives the radial load constant for the pump, which ideally should be constant over the capacity range. Table 4 presents the results of these calculations.

EFFECT OF SHAFT DESIGN

If the shaft deflection constant or curve is not established experimentally, the above procedure does not include a factor for the difference between the actual and the calculated shaft constant. It has been shown (*3*) that when a shaft has several changes in diameter and depending on the ratio of the change, the actual deflections from a given weight will be greater than the value calculated from the shaft dimensions. This factor can range from 1.0 to 1.25. If more exact values for W_r and the radial load constants are wanted, this factor must be taken into consideration.

† The constants for Equations (6) and (6B) may also be evaluated indirectly or the relationship between Y and W or actually Z and W established by experimental measurement. This is done by placing weights on the shaft at the impeller centerline. The shaft should be mounted in the pump's bearing bracket with the impeller and casing removed. The shaft need not be rotated; static measurements are adequate. The deflection of the shaft should be measured at two points, at the impeller centerline location and at the point on the shaft outside the casing where the measurements will be made with the dial gauges for unbalanced radial load. The values for W corresponding to Z_x can be read from the experimental curve.

‡ See footnote † for application to Equation (7A) and (8B).

SHAFT DEFLECTION AT IMPELLER

With the values for W_r at different pump capacities, the shaft deflections at the impeller centerline can be calculated with Equation *(7A)* for the effect of bearing deformation and unbalanced radial load. If the weight of the impeller is to be included, the deflection caused by its weight is calculated with Equation (6) (K_{max} is obtained from Equation *(6A)*). Because the deflection from unbalanced radial load and the displacement from bearing deformation are not vertical, the vector sum of the deflections caused by the impeller weight and the radial load must be calculated to obtain the maximum value for shaft deflection. Results of the operations just described are summarized in Table 4 without the weight of the impeller.

RADIAL LOAD CONSTANT

The constant k_r in Table 4 has a value of approximately 0.28 for part of the capacity range, and the average value is 0.252. Errors in measurement, wear of the dial gauge spindle, looseness in the bearing mountings, inelasticity of

Development of Equations

In order to determine the amount of shaft deflection at the impeller centerline and the amount of the loads on the bearings for a centrifugal pump, it is necessary to develop: (1) equations that relate the unbalanced radial load at the impeller with the impeller dimensions and the head developed by the pump at different capacities, (2) equations that relate the unbalanced radial load at the impeller with the bearing loads, (3) equations that relate shaft deflection or displacement with deformation in the bearings resulting from loads on the bearing, (4) equations that relate shaft deflection with the unbalanced radial load, the impeller weight, and the shaft dimensions, and (5) equations that give the sum of the shaft deflections for unbalanced radial load, bearing deformation, and impeller weight for the total deflection. The total deflection of the shaft can be calculated for any point along its length.

Owing to space limitations, only a summary of the equations * referred to in this paper will be presented as follows:

* Equations developed for this paper may be obtained from A.D.I.

UNBALANCED RADIAL LOAD

$$W_r = \frac{KhD_2B_2S}{2.31} \qquad (1)$$

UNBALANCED RADIAL LOAD CONSTANT

$$K = k_r\left[1-\left(\frac{Q}{Q_n}\right)^2\right] \qquad (1A)$$

DISPLACEMENT CONSTANT FOR BEARINGS

$$K_e = \frac{k}{43.3}\sqrt[3]{\frac{1}{z^2d}} \qquad (4C)$$

SHAFT DEFLECTION EQUATIONS

For bending only

$$Y_{max.} = K_{max}W \qquad (6)$$

$$K_{max} = \frac{1}{3E}\left[\frac{b^3}{I_b} + \frac{a^3-b^3}{I_a} + \frac{a^2l}{I_1}\right] \qquad (6A)$$

$$Y_x = K_xW \qquad (6B)$$

$$K_x = \frac{1}{3E}\left[\frac{b^3}{I_b} + \frac{a^3-b^3}{I_a} + \frac{a^2l}{I_1} - \left(\frac{3b^2}{2I_b} + \frac{3(a^2-b^2)}{2I_a} + \frac{al}{I_1}\right)x + \frac{x^3}{2I_b}\right] \qquad (6C)$$

For bending and displacement

$$Z_{max.} = K_{max}W + \left[\left(\frac{L}{l}\right)^{2/3}K_{e2} + \left(\frac{a}{l}\right)^{2/3}K_{e1}\right]W^{2/3} \qquad (7A)$$

$$Z_x = K_xW_r + \left[\left(\frac{L-x}{l}\right)\left(\frac{L}{l}\right)^{2/3}K_{e2} + \left(\frac{a-x}{l}\right)\left(\frac{a}{l}\right)^{2/3}K_{e1}\right]W_r^{2/3} \qquad (8B)$$

Notation for Equations

a = overhang or distance between centerlines of impeller and inboard bearing, in.

b = distance between centerline of impeller and a change in cross-section of shaft, in.

B_2 = over-all width of impeller at periphery, in.

d = diameter of the ball in a ball bearing, in.

D_2 = diameter of impeller, in.

E = modulus of elasticity for shaft material, value used in all calculations is 3×10^7, lb./sq.in.

F_a = axial load on bearing, lb.

F_r = radial load on bearing, lb.

h = total head developed by pump, ft.

I (with subscript) = moment of inertia for shaft at cross-section as indicated by subscript (in.)[4]

k = elastic deformation constant for ball bearings

k_r = radial load constant

K = unbalanced hydraulic radial load constant

K_e = displacement constant for bearings, position of bearing is indicated when a numerical subscript is included

K (with subscript) = shaft deflection constant at point indicated by subscript, in./lb.

l = distance between centerlines of inboard and outboard bearings, in.

L = distance between centerlines of outboard bearing and impeller, in.

L_s (with subscript) = minimum bearing life, position of bearing is indicated when a numerical subscript is included, yr.

Q = volumetric rate of flow, gal./min.

Q_n = volumetric rate of flow at point of maximum efficiency, gal./min.

R_1 = radial load on outboard bearing, lb.

R_2 = radial load on inboard bearing, lb.

S = specific gravity of liquid

W = net or total unbalanced radial load at impeller, lb.

W_i = weight of impeller, lb.

W_r = hydraulic radial load at impeller, lb.

x = distance along pump shaft from impeller centerline, in.

y_e = amount of compression in ball bearings, position of bearing is indicated when a numerical subscript is included, in.

y (with subscript) = dial gauge readings as indicated by subscript, in.

Y (with subscript) = static shaft deflection at point indicated by subscript or subscripts, in.

Y_e = shaft displacement at centerline of impeller from bearing compression, in.

Y_{ex} = shaft displacement from bearing compression at x distance from impeller centerline, in.

z = number of balls in ball bearing

Z (with subscript) = static shaft deflection plus shaft displacement at point indicated by subscript, in.

α = contact angle in ball bearing, deg.

SUBSCRIPTS

$a,b,1,x$—refers to section of shaft where diameter, location, or moment of inertia is under consideration.

max.—refers to maximum value at impeller centerline.

the shaft would seriously affect the values for k_r for capacities around the point of maximum efficiency where the loads are small. It is believed that if these factors were not present, the values for k_r in the range of about 1,300 to 2,090 gal./min. would be approximately 0.28. Therefore, it can be concluded that the constant k_r in Equation (*1A*) has a value of approximately 0.28 for the capacity range of this pump with a cutwater radius to impeller radius ratio of 1.10.

The discussion about the constancy of the value of k_r over the capacity range of the pump is only of academic interest. When the pump is operated in the lower part of its capacity range, it is more important to know the magnitude of the larger values for the unbalanced hydraulic radial load. This is necessary to determine whether the shaft will be stiff enough to prevent wear at the impeller leakage joints, trouble with leakage through the packing, and scoring of the shaft. Values for total shaft deflection at the impeller centerline shown in Table 4 and values for shaft deflection at the point of measurement shown in Table 3 indicate that it is too large. At present, experience indicates that the deflection of the shaft where it leaves the packing should not exceed about 0.002 in.

Because this pump has an axial clearance for its leakage joint, the values for shaft deflection shown in Table 4, although large, are not great enough to cause the impeller to rub at the leakage joint or the casing wall. However, if this pump had radial clearances at its leakage joint of 0.005 to 0.010 in., the deflection of the shaft would have to be less than these clearances for the pump to be operated over its full capacity range. Otherwise, it would suffer damage or the clearances would be increased by wear. If the material at the clearances is of stainless steel construction, galling and possible breakage of the shaft could occur. If the pump is to be operated with radial clearances less than the maximum deflection, precautions should be taken by installing a by-pass with an orifice in the line and arranged so that the pump will always operate out on the curve (where shaft deflection is less than the radial clearance) even if the discharge valve is closed.

Since the deflection of the shaft where it leaves the packing should be limited to about 0.002 in., it is evident that for pumping rates below about 1,200 gal./min., the shaft deflection present is too great for satisfactory maintenance-free operation because of possible troubles with the packing.

By reference to Table 4 it should be noted that for this pump shaft displacement at the impeller centerline from bearing deformation is not of great importance.

Table 3.—Shaft Deflection at Point of Measurement

capacity (gal./min.)	gouge No. 1 * $Y_{e1} \times 10^3$ in.	gouge No. 2 ** $Y_{e2} \times 10^3$ in.	deflection *** $Z_e \times 10^3$ in.	angle from vertical axis deg.
0	−2.95	+5.02	+5.83	75.4
200	−2.63	+4.92	+5.48	73.2
800	−2.29	+3.00	+3.77	82.3
1300	−0.82	+0.83	+1.17	89.6
1600	+0.35	−0.15	−0.38	−67.2
1900	+0.79	−0.18	−0.81	−57.8
2090	+1.23	+0.07	−1.23	−48.2

* Datum reading = 0.00175 in.
** Datum reading = 0.00223 in.
*** Plus sign indicates deflection to the right; negative sign, deflection to the left.

Table 4.—Unbalanced Radial Load, Constants, and Shaft Deflection at Impeller Centerline

				shaft deflection without impeller weight		
capacity (gal./min.)	W_r (lb.)	K	k_r	Y_e $\times 10^3$ in.	$Y_{max.}$ $\times 10^3$ in.	$Z_{max.}$ $\times 10^3$ in.
0	335	0.290	0.290	1.52	13.5	15.02
200	311	0.276	0.281	1.44	12.55	13.99
800	209	0.201	0.281	1.11	8.42	9.53
1300	58	0.066	0.264	0.47	2.34	2.81
1600	−17	−0.023	0.173	−0.20	−0.67	−0.87
1900	−39	−0.077	0.128	−0.36	−1.56	−1.92
2090	−62	−0.326	0.347	−0.49	−2.48	−2.97
			0.252 (avg. value)			

Comparison of Shaft Deflection Values Without and With the Impeller Weight

The impeller for this pump under discussion weighs 45 lb. Its weight does not have an important effect on the deflection of the shaft except to change the direction of the deflection, especially when the values for unbalanced radial load are low. This is illustrated in Table 5 for comparison with the values presented in Table 3. The buoyant effect of the water on the impeller was not included in the calculations.

Radial and Axial Loads on Bearings and Bearing Lives

The values for axial load and the bearing life are calculated by the methods outlined in the paper by Ullock (*3*). The load-carrying capacities for the bearings and the equation

Table 5.—Direction and Total Deflection of Shaft

capacity (gal./min.)	head (ft.)	with impeller wt. $Z_{max.} \times 10^3$ in.	angle from vertical axis deg.
0	92	14.74	83.0
200	90	13.51	81.3
800	83	9.43	94.9
1300	70	3.49	127.6
1600	56	−2.05	−158.5
1900	40	−2.01	−126.6
2090	15	−2.25	−95.0

Table 6.—Radial and Axial Loads on Bearings and Minimum Bearing Lives

	net radial load	radial load at bearings		axial load at outboard	bearing lives	
capacity (gal./min.)	at impeller W_r (lb.)	inboard R_2 (lb.)	outboard R_1 (lb.)	bearing F_a (lb.)	inboard L_{n2} (yr.)	outboard L_{n1} (yr.)
0	+335	+642	−314	−1715	1.1	0.27
200	+311	+590	−289	−1665	1.3	0.29
800	+209	−406	−199	−1485	3.7	0.43
1300	+ 58	+144	−70.7	−1148	82.9	1.02
1600	− 17	−81.5	+39.9	−785	459	3.18
1900	− 39	+80.3	+39.2	−215	482	13.9
2090	− 62	−90.2	+44.1	+277	339	6.6

Note: Plus and minus signs denote only the relative change in direction of the loads from one quadrant of the area in a circle to another quadrant.

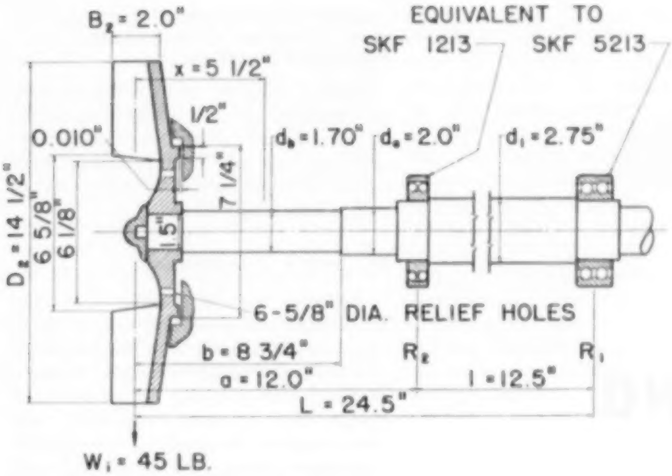


Fig. 1. Impeller, shaft, and bearing assembly.

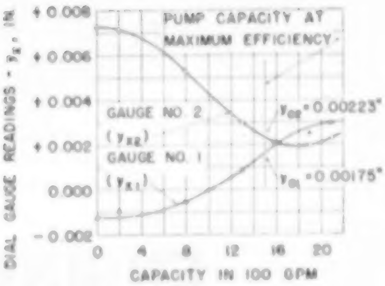


Fig. 4. Plot of dial gauge readings.

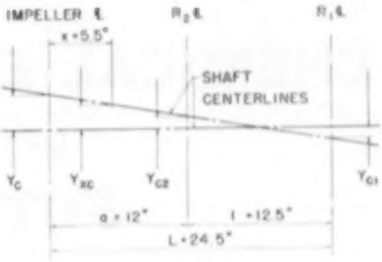


Fig. 6. Displacement of shaft centerline by deformation in the bearings.

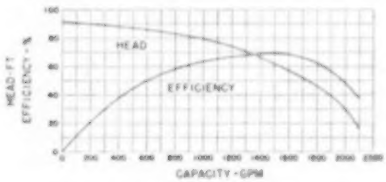


Fig. 2. Performance curve.
Pump speed: 1194-1184 rev./min.
Pump specific speed: 2,100 rev./min.

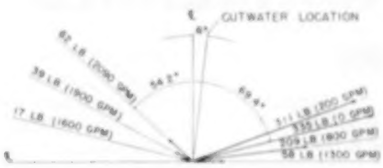


Fig. 5. Direction and amount of unbalanced radial load at impeller centerline.

for combining axial and radial loads to an equivalent radial load were obtained from Catalogue No. 350 of SKF Industries, Inc.

It is important to note in Table 6 that the bearings are not large enough to carry the loads imposed on them for a desired minimum bearing life of two years.

The outboard or thrust bearing has the lowest life because of the high axial load imposed on it. This range in minimum bearing life of 0.27 to 1.0 yr. for the capacity range of zero to 1,300 gal./min. is in what might be called the twilight zone. The user is not likely to recognize from experience that this bearing is in a zone between inadequate and adequate life because the bearing used in this pump may have a life less than 0.27 to 1.0 yr. minimum life or it may have lives that range up to about twenty times these minimum lives.

It is interesting to note that if a medium series bearing were used instead of the light series, the range in the minimum bearing life would be 1.2 to 4.6 yr. If duplex angular contact bearings of the light series were used, the range in the minimum bearing life would be 1.6 to 6.1 yr. For a little extra cost, the possibility of premature failure is reduced by a factor of five or more. In addition, the inboard and outboard bearings would have comparable lives.

It is evident from Tables 5 and 6 that this pump should not be operated at capacities below about 1,200 gal./min. if trouble with leakage from the stuffing box and premature failure of the bearings are to be avoided.

For chemical process pumps, such as the pump used for illustration, it appears to be axiomatic that if the shaft is stiff enough for packing requirements, the bearings mounted on the shaft are likely to be of sufficient size, at least for the inboard position. Because the shaft is reduced in diameter for the coupling, the outboard bearing could be too small. If the shaft is not greatly reduced in size at the impeller mounting and at the coupling, it is likely to be oversized for the torque to be transmitted.

Summary

A method for measuring shaft deflections has been described which can be applied by the pump user to centrifugal pumps that appear to be inadequate in mechanical design because of repeated failures. This method has been applied to pumps with speeds up to 3,500 rev./min. Shaft deflection is caused by impeller weight and unbalanced radial forces developed in the pump casing. These forces cause an additional displacement of the shaft because the ball bearings are elastically deformed. The hydraulic radial load can be large in value and has a definite direction; its magnitude and direction will vary with the pump capacity.

While not of major importance for the pump under consideration, the effect of impeller weight and elastic deformation in bearings on shaft deflection has been demonstrated.

For the pump under test, the values obtained for shaft deflection and bearing lives indicate that trouble may be expected with leakage and scoring of the shaft at the packing gland and failure with the bearings. This situation may be improved by increasing the diameter of the shaft at the overhang and using bearings of larger size.

Literature Cited

1. Palmgren, Arvid, "Ball and Roller Bearing Engineering," SKF Industries, Inc., Philadelphia, 2 ed. (1946).*
2. Stepanoff, A. J., "Centrifugal and Axial Flow Pumps," John Wiley & Sons, Inc., New York (1948).*
3. Ullock, D. S., Chem. Eng. Progr. 51, 207 (1955).

* On file with A.D.I. in Development of Equations.

Presented at A.I.Ch.E. forty-eighth annual meeting, Detroit, Michigan.

ENGINEERING

AND

CHEMICAL ENGINEERING

OF THE

FUTURE

Joseph C. Elgin

School of Engineering
Princeton University

What is to be the future education for chemical engineering? Exploring the future in any field is an intriguing and exciting pastime, and it is particularly so if the subject involves education, scientific discovery, or engineering development. This article is an effort to predict the character of the university education for chemical engineering in 1975.

The text is based on the talk given by Dean Elgin at Lake Placid last September. It was truly one of the outstanding events of the meeting, and the discussion which it aroused has not yet subsided. Whether or not one's own picture of the world of engineering in 1975 coincides exactly with Dean Elgin's, it is still rather sobering to consider that the men who will be running things at that time are being trained now.

Chemical engineering is first *engineering*, and second, *chemical*. Its basic characteristics are those of engineering in general. The elements steering its future education are the same as those for any engineering field.

Education Change a Slow Transition

Changes in engineering educational procedures are the result of slow transition, more so perhaps than for most other disciplines. They are evolutionary, not revolutionary. Twenty-five years are not too long a period over which to experiment in order to arrive at a suitable method of implementing a concept or a trend. Engineering is complex, dependent upon science, industry, and even developments in human affairs. Fundamental engineering knowledge develops gradually. Faculties are often, and rightly, cautious and slow to act. In courses and curricula, elements of the old and of the new exist side by side, just as an old chemical plant or process operates profitably and peacefully adjacent to a neighbor of the latest design and technology.

CONCEPT OF ENGINEERING EDUCATION MORE IMPORTANT THAN DETAILED CURRICULUM CHANGES

Finally, in order to limit our degrees of freedom, we will restrict ourselves to the *university* education for engineering, and we will deal primarily with ideas, concepts, and the philosophy of future education.

The Nature of Engineering

Although we may differ over the knowledge and education needed, most engineers will agree that the essential, professional, and distinguishing characteristic of engineering is *design*—the design of a structure, apparatus, machine, circuit, instrument, manufacturing process, plant, or product. This may be an analysis or a synthesis of a design. Both depend essentially on the same knowledge and tools. The reduction to practice, the operation, supervision, and use of a design, or the distribution of its products to the consumer may be carried out also by engineers, but these functions are supplementary to the essential design activity. These are auxiliary functions which, because of his education and training for the fundamental activity, the engineer is qualified to perform well.

An engineering design must not only be scientifically and technically correct, but it must be correct in its economics as well. Its fundamental purpose is to benefit human beings. Hence it must be a correct solution in terms of human relationships, values, and welfare. An engineer also must live and work with his colleagues and other human beings. The making of a technically correct design is based on a knowledge of mathematics, the natural sciences, and the engineering sciences supplemented by engineering art and experience. The correctness of its economics is controlled by the principles of economics and social science. To make it correct in its basic purpose of promoting human welfare, the engineer must depend upon a knowledge of human relationships and values as taught by the humanities. If this view is acceptable, engineering is, and engineering education should be, a *blend* of four basic ingredients: mathematics and natural sciences, engineering art and science, economic and social science, and the humanities. My guess for the future is that a homogeneous blend of these four ingredients, each assigned equal importance in an engineering education, will be a universally accepted guiding principle.

Liberal Arts in Engineering Education

The effort to broaden engineering education in the liberal arts has been a

major trend over the past twenty-five years. Its importance is well recognized and discussed at length in the recent report of the American Society for Engineering Education on the *Evaluation of Engineering Education* (*1*). There is not yet full agreement on the best method of providing for the liberal arts in an engineering program, and the degree to which the trend has been implemented differs among institutions and curricula. There is still some reluctance to accept the social sciences and humanities as an essential part of engineering and to accord them equal importance with scientific and engineering subjects. However, it is a good prediction that experimentation in means of incorporating them will continue unceasingly and that they will eventually be fully accepted as an integral part of any engineering curriculum. In the education of the engineer in 1975, they will be accorded equal importance with scientific and engineering subjects.

Engineering Science and Engineering Art

A second major point about the future which seems inevitable is that an engineering science, now young, will mature and will entirely replace engineering art as the basis of education. History indicates that engineering develops first as an art, based on experience and practice. With the aid of pure science and research, this is followed by the development of the underlying engineering science peculiar to the art. This stimulates the development of still new engineering art, which in turn leads to further broadening and deepening of our knowledge of the engineering science. This is also the history of chemical engineering.

Because of the complexity of engineering problems and the widening horizons of engineering, it is improbable that engineering art will all be reduced to an engineering science within the foreseeable future, but our knowledge of the engineering sciences and the ability to generalize complex problems in terms of basic principles is rapidly increasing. In many engineering fields, including chemical engineering, the engineering science already has attained a state of development where it has become the basic knowledge upon which much of the practice of engineering rests. It has already begun to assume a significant role in the university education for engineering.

The recognition and adoption of the engineering sciences as the central theme of an engineering education and continued progress in their development will be the major trend of the next quarter-century. The initial phases are already evident and also are fully recognized in the recent report previously mentioned (*1*). The implementation of the engineering science concept by changes in curricula has barely begun. The full transition between art and science will necessarily be slow. It must parallel the development of our knowledge and ability to generalize in engineering terms. The speed with which it is accomplished will undoubtedly differ for the different branches of engineering, but I believe that by 1975 all chemical engineering education in the university may be based upon the engineering science.

WHAT, SPECIFICALLY, IS ENGINEERING SCIENCE?

If then, future education is to be based on engineering science, perhaps we should understand what we mean by the term. It indicates a body of organized knowledge distinct from either pure or applied science. In some fields, its outlines are barely recognizable; in others, it can even now be described with reasonable clarity. My own understanding of engineering science is that it is the science of combining, generalizing, and translating the laboratory findings and theoretical principles of pure science into the complex, large-scale structures, machines, and operations of industry.

An engineering problem inevitably involves the action and interaction of a complex series of variables and scientific principles, all operating simultaneously. This combination creates from their interaction a new set of principles. New generalizations are needed for predicting the results of their behaviour in any real situation. This is the concern of engineering science. An engineering problem can rarely be answered by the sequential application of the isolated scientific principles developed by pure science for a single or small group of variables and usually for idealized circumstances. Engineering science is therefore more than applied science in the usual sense.

Furthermore, the engineering problem, for the solution of which all factors must be considered as a whole, is usually so complex that a theoretical or an exact, rigorous mathematical statement is rarely possible. With a recognition of this, engineering science seeks to formulate valid but less rigorous generalizations which approximate the truth. Even then the number and complexity of the variables in many engineering situations are so great that experience, *i.e.*, the art, must be added to the engineering science in order to provide an acceptable answer. In contrast to pure science, engineering science accepts the complete situation as it actually exists, and attempts to provide a technically correct answer translatable into some form of action.

RESPONSIBILITY OF INDUSTRY IN TEACHING THE ART

We have predicted that in the years ahead teaching the engineering art and methodology will no longer be provided for in a university education for engineering but that it will continue to be an essential part of engineering for many years. How will it be acquired? I believe that the responsibility for educating the engineer to full professional status in the immediately useful art will be recognized and assumed by industry. The period of time before this situation becomes a reality will probably differ for various engineering fields, but I am confident that the time will ultimately arrive.

In my opinion the art can be acquired only through education on the job acquired by experience and practice. This is especially true of the engineering and technological specialties. It can be neither effectively nor satisfactorily taught in the university. In the university only the past art can be taught, and teaching the engineering science will be more effective. In the past we have, of necessity, attempted to teach the art as a part at least of a college education, largely because we knew only the art. This is because engineering science was not developed and available. The result has been a source of continued criticism. What appears to be an expression of this same thought, voiced with increasing frequency of late, are the pleas to engineering educators to teach the fundamentals to the prospective engineer in college. The seeming failure of educators to heed these pleas immediately comes from a lack of a clear definition of a "fundamental," and a forthright statement of the acceptance by industry of the responsibility for educating the engineer in the engineering art. In his recent paper before the Houston meeting of A.I.Ch.E., Professor R. R. White (*2*) of Michigan seems to be expressing similar ideas.

Industry is resourceful and farsighted. As it accepts the responsibility for providing a means of educating the engineering graduate in the art and for developing him to full professional status, it will devise new methods and procedures to accomplish these. Some larger industrial organizations already have

recognized the necessity, if not the responsibility, and have established their own internal educational programs. Part of the pattern will undoubtedly be the full acceptance of the responsibility by larger companies as a part of their personnel policy, but this solution may not suffice for all industry or for the profession as a whole. Smaller organizations will probably find it difficult to administer and to afford an educational program. Once the problem is fully recognized and accepted, the ultimate solution may well be through the organization of groups of industries. It seems less likely that the responsibility should or can be assumed by the professional engineering societies.

Chemical Engineering Education

As one turns specifically to chemical engineering it should be noted that chemical engineering education in the present century can be visualized as falling into four stages or periods as shown in Table 1.

The dates selected to separate the divisions between the periods are purely arbitrary. Actually the changes have been slow transitions marked by no sharply defined dates or rapid breaks.

Historically, the first stage was characterized by the recognition and qualitative description of the art. In this early stage, education consisted of the then established principles of mechanical and civil engineering, chemistry, and physics. There was no recognition that the combination of these principles, plus the need to develop entirely new generalizations for chemical engineering, would and must generate a new and unique engineering science.

This recognition did not commence until the late twenties. There was a long argument as to whether chemical engineering was engineering or chemistry, meaning by engineering, mechanical and civil. The early curriculum was composed of a group of mainly empirical principles drawn from the then standard courses in mechanical, electrical, and civil engineering, heterogeneously mixed with mathematics, physics, and chemistry, and with various courses in descriptive technology added.

PERIOD OF TRANSITION—STAGE 2, 1922-1950

The second stage, from which we are just beginning to emerge, opened with the introduction of the Unit Operation concept in the famous "Little" report of 1922.

In this period, based on the unit operation organization, chemical engineering was established as a distinct profession. This concept provided an extraordinarily useful framework for education and for the organization of the chemical engineering science. It seems clear that originally the thinking and the emphasis were still on the art of the unit operations. At this stage there was clearly no recognition of a chemical engineering science.

In the past twenty years, not only the art but many of the basic principles and generalizations of the science underlying the art of the unit operations have been developed. Broad correlating principles have been discovered and established. This has been a period of transition. Education has involved a mixture of the chemical engineering art and the science. However, the science of chemical engineering has clearly begun to emerge.

Table 1.—Stages in Chemical Engineering Education

I. *1890-1922. Chemical Engineering—the art:* The art is recognized and qualitatively described. Education directed to the art.

II. *1922-1950. Chemical Engineering—art and science—period of transition:*
Unit operation concept introduced.
Unit operation principles develop, setting stage for recognition of the science.
Education focused on unit operations and technology.

III. *1950-1975. Chemical Engineering—the engineering science:*
Fundamental generalizations of chemical engineering science emerge and established as focal point of education.
Unit operational organization and emphasis on the art disappear from the curriculum.

IV. *1975-2000. Fields of Engineering—*
These merge into a few broad principles of a single engineering science on which education is based.

Unit Processes

The emergence of chemical engineering science was materially accelerated in the late thirties and early forties by the dissatisfaction of a group of chemical engineering educators with the unit operations alone as the complete focus of education. This group wished to recognize that chemical engineering was heavily concerned with processes of *chemical* change, as well as the physical changes covered by the unit operations. In order to satisfy this concern, the now-familiar organization of chemical processes called *unit processes,* was more or less widely grafted into the educational structure.

The unit process scheme, certainly in its early conception and implementation, was based largely on industrial art and technology. It has not been nearly so successful an educational device as the unit operations have been, but has resulted, however, in a speedier recognition that underlying the unit processes is a second branch of fundamental chemical engineering science. This new engineering science, at this stage of progress, is variously organized and identified in chemical engineering education by titles such as Chemical Reactor Design, Chemical Engineering Kinetics or Industrial Kinetics.

Chemical Engineering Science Emerges

This brings us to the threshold of the future, stage 3, Table 1. A reasonable prediction is that by the year 1975 the transition from art to science in chemical engineering education will be substantially complete. We can understand better what this means for the education of the future chemical engineer if we examine briefly the nature of chemical engineering science.

In very simple terms, the essential problem of chemical engineering science is "scale-up." The science is concerned with the conduct of chemical and physical changes, singly and together, and with the separation of the components of mixtures when the amounts or masses of materials involved are relatively large. Its province is the behavior of molecules or atoms in large groups or masses rather than as individuals or in small families. We may classify it into two branches: (1) that underlying processes of physical change alone, and (2) that underlying combinations of physical and chemical change. The two have many common cross-links in the basic scientific principles involved.

The *science* originates from a few simple scientific facts. No over-all process of physical or chemical change consists solely of a single independent action or reaction. Each consists of a complex series of numerous chemical and physical processes proceeding together in parallel and sequence. These are usually interrelated. They profoundly influence one another. Rarely on large scale can any of these individual processes be neglected. Thus, the over-all chemical process, besides the progress of the change in chemical structure itself, involves the movement of materials into, through, and out of the reaction zone; mixing and unmixing of molecules; transfer of mass or molecules between points within, transfer between the boundaries of the reacting mass, or between phases; exchange of and transformation of energy; and the evolution or absorption of heat. Each of these proceeds at its own characteristic speed, and the net result is controlled by the interaction of the relative speeds and equilibria of all.

Now the speeds of the physical processes, such as heat and mass transfer, are determined by the surface area, which is fixed by the linear dimensions

of the mass. Those of the actual chemical processes themselves are independent of the size of the mass. The quantities of energy, heat, and mass involved in the change, however, depend upon the mass and the volume, and hence the ratio of the quantity to its surface area, or to the surface of the walls of the containing vessel, increases with the linear dimension. This means that the ratio of the quantity of mass, heat, or energy to the area available for transfer or exchange, other conditions being the same, inherently increases as the mass increases. Unless provided for by some new expedient, the results obtained from a chemical process depend, therefore, inherently upon the scale of operation.

Chemical engineering science recognizes and accepts as its problem the complete over-all process of chemical and physical change and the effect of scale upon it. It seeks to generalize it in order to predict rigorously and quantitatively the results for operation on any scale. Chemistry, on the other hand, neglects the effect of scale and considers only the chemical reaction itself, independently of the other processes. Or else it deals with the operation on such scale and under such circumstances that the speed of isolated chemical change alone dominates the entire system. In order to scale up the chemical reactor, chemical engineering must evaluate quantitatively not only the speed of the chemical reactions themselves but also the rates of heat and mass transfer and of the mixing and flow processes as well. This is the heart of the problem of one important branch of chemical engineering science. In education, this subject is presently being approached through various combinations of the principles of the component parts, such as fluid mechanics, mass, momentum, and heat transfer, particle dynamics, and so on. The organization of the chemical engineering curriculum around such subject matter has barely begun.

FUTURE OF UNIT OPERATIONS—

The second branch of chemical engineering science

The unit operation concept recognized in the early twenties that the separations of the components of complex mixtures are based upon certain standard procedures independent of the specific kinds of substances concerned. It classified this knowledge according to the particular combination of phases entering into the separation. Advancing knowledge during the past twenty-five years has permitted us to see that separations (irrespective of the particular combination of phases involved) depend upon the same general scientific principles.

The principles of countercurrent and stagewise operation, the equilibrium stage concept or the mass transfer concept of design, and the concept of reflux are, for example, general principles independent of what particular phases are involved in processing. These together with the principles of the material balance, the heat balance, phase equilibrium (chemical engineering thermodynamics) mass, heat, and momentum transfer and fluid mechanics, and their combination into generalizations for the over-all process are the subject matter of the second main branch of chemical engineering science. In similar manner, heterogeneous separations, filtration, centrifuging, and the like can be generalized in terms of the application of mechanical forces and the flow of fluids through beds of particles or through semipermeable membranes.

Today we are just beginning to organize chemical engineering education in the university to conform with this second branch of chemical engineering science and the principles involved. By 1975, it is my guess that it will be an accepted organization of subject matter and that treatment in terms of the individual unit operations will have disappeared.

New Areas of Chemical Engineering Science

New areas are beginning to appear as important parts, and perhaps principles, of future chemical engineering science. The application of the mathematics of statistics and probability to the conduct of chemical reactions; the performance by means of machines of the mathematical computations required in quantitative prediction and design; the production, care of and use of neutrons, sometimes called "nuclear engineering"; and the scientific control of large-scale chemical and physical operations are beginning to appear in education.

In a sense the first two of these, namely statistics and machine computations, are tools likely to become increasingly important to chemical engineering in the future. Professor E. F. Johnson, Jr., (*3*) considers the concept of control to be one of three basic concepts of chemical engineering. He defines it "as the regulation of processes, equipment and plants to maintain specific patterns of operating behavior." It is a fair prediction that this subject is destined for increasing importance in the education of the chemical engineer.

For the moment, it does not appear that nuclear processes will introduce basically different concepts into chemical engineering science. They do require consideration of the effects of radiation on materials, including damage, shielding, and protection of personnel from radiation. But these seem mainly to involve new techniques, and the application of established principles under different combinations and conditions of energy release, heat transfer, and temperature. Many techniques are likely to lie in the realm of engineering art for many years.

The Long-Range Future

Thus far we have been thinking primarily of the next twenty-five years. For the years beyond that we can make only a nebulous guess. A recent remark by Dean Gordon B. Carson of Ohio State University gives us perhaps some clue. Prefacing a report on education in nuclear engineering (*4*), he observes, "As engineering moves steadily out of the area of art, and into the area of the science, it appears that the similarities between the various branches (of engineering) become greater than the differences." The indication is that engineering science eventually may reduce and simplify itself into the application of a few fundamental principles, for example, transformations of energy, with no distinction as to kind of energy.

Even more fundamental generalizations and principles underlie the chemical engineering science which I have depicted. The processes with which it is concerned are determined ultimately by exchanges and balances of forces, of energy, and of mass. Today, our knowledge is insufficient to write in usable terms, or to deal practically with the equations and mathematical relations expressing these balances in specific processes and operations. Perhaps it is not too bold to predict that these principles alone, without regard for the specific kinds of chemical structure, physical properties, action or reaction, will constitute the engineering science in which the chemical engineer of the year 2000 will be educated.

Literature Cited

1. Am. Soc. Eng. Ed., Report of the Committee on Evaluation of Engineering Education (June 15, 1955).
2. White, R. R., *Chem. Eng. Progr.*, **51**, 341 (1955).
3. Johnson, E. F., Jr., Paper presented before the Symposium on Process Instrumentation and Control, Am. Soc. Eng. Ed., Pennsylvania State University (June, 1955).
4. Carson, G. B., Report on education in nuclear engineering.

Condensed from paper presented at A.I.Ch.E. meeting, Lake Placid, New York.

GROWTH AND MANAGERIAL

It is evident that the process industries are placing greater emphasis on the need for long-range planning with regard to resources, methods, and especially to manpower. The fantastic speed with which the future rushes down upon us, however, makes it increasingly difficult to separate today and tomorrow into neat little packages of thought and planning.

Which, for us in industry, is today, and which is tomorrow? The development of men for the work of managing is one point at which we need to talk about the future as if it were already with us. The considerable literature of the past ten years which deals with the work of managing seems to supply all kinds of answers to all kinds of questions except the one of "What do I do to provide better business management *now?*"

We in management have two kinds of work to perform. One, of course, is to plan for the long-range future of each of our companies or those parts of our companies which lie within our areas of personal responsibility. The other kind of work—needed to supply the firm foundation of this future planning—is the managing and running of the business which is in the "here and now" and for which answers, scaled to the limits of current resources, have to be provided.

Manager development is a problem for "now." It is a process which can be, and definitely needs to be, going on in every responsible and forward-looking business and industry at this moment. There is, after all, not much sense in planning for growth ten years from now while letting a company lie fallow until that day arrives. It should be possible to plan in terms of what can be done within, say the next eighteen months—things which will produce immediate evidence of growth, of increased stability, and, inevitably, of a greater opportunity to enjoy fuller rewards for our efforts.

It is especially true in the chemical process industries which involve a constant flow of new kinds of materials, new processes, and new demands, that the need for considering the "world of the future" as being already upon us is most apparent. A good part of the thinking in these fields has been concerned with how to develop the kind of men and the quantity of men needed to meet business objectives.

Peter Drucker, in his book, "The Practice of Management," writes:

"The demands on the skill, knowledge, performance, responsibility, and integrity of the manager have doubled in every generation during the past half century. Things, which in the twenties only a few pioneers in top management were aware of, we now expect young men straight out of school to be able to do.

"Daring innovations of yesterday—market research, product planning, human relations, or trend analysis, for instance—have become commonplace. Operations Research is fast becoming so. Can we expect this almost explosive increase in the demands of the manager to continue? And what can we expect to be demanded of the manager of tomorrow?"

We can answer Mr. Drucker's questions, but in order to do it to our own satisfaction, I think we will necessarily have to examine the need for an orderly approach—call it a philosophy—toward manager development.

"Philosophy" of Manager Development

There have been a great many studies made in the past thirty years of how business enterprises grow. They have been made by people connected with "big" businesses, by people who wanted to plan for a similar growth in their own companies, and, finally, by people who thought that anything bigger than a business you could carry in your hat was somehow either too complex or too big for really profitable operation.

All of them—even from such very different frames of reference—have come to at least one uniform and significant opinion, and that is that no matter what the product, geography, or economic climate may be, the physical growth of a company paralleled, although following, a growth toward what we can call "managerial maturity." Growth is the end-product of sound planning, and sound planning, of course, depends not only on vision but also on the maturity which managers bring to such vision.

These simple facts have been evident and true as far back as you care to trace them, and there is no reason to doubt that they will be true in the future. They emphasize the point that before we can lift our sights to new horizons, we must make provision to increase our capacity to manage our existing businesses in a way which will permit achievement of these higher objectives.

Now, why do we need anything so elegant-sounding as a "philosophy" of manager development? You might ask what is wrong with the way we have been developing managers in the past. Haven't they done a good job? Haven't their businesses grown under their leadership? Isn't it pretty obvious that there has been enough development in the numbers of men to meet the needs of industry?

My answer to these questions is that, *first*, there is nothing wrong with the way we have been developing managers in the past, providing we were developing them only for the past. But, we can't assume that things are not going to change radically in the future when things are already changing so rapidly today. What we need to do is to adapt and add to the techniques of manager development which have served us so well. Such techniques must fit the needs of the economy as it will presently be.

Second, of course, managers have done a good job, and businesses have grown under their guidance. However, it is this very growth which makes a new examination of managing so important, for along with it has come a galloping increase in the complexity of the manager's job.

Third, there is the matter of whether there has been an adequate supply of managers in the past. There is an old rule of logic which says you cannot win an argument on a hypothesis contrary to fact. We can only guess at where the economy would stand, today, if more of us had recognized more fully and more widely the need for a more intensive and orderly approach to manager development fifteen or twenty years ago.

There are still many people in our modern industrial world who believe that what was good enough for the past—what, in other words, brought us to our present position of world industrial leadership—can continue to serve us with equal results and reliability in the future. I think that they may fail to realize that "good enough for daddy" doesn't have much real meaning because what they are looking at, and clinging to, is a way of working which was consistent only with the circumstances of a world and the conditions of an economy no longer present, or possible.

From an address at the National Meeting, A.I.Ch.E., Lake Placid, New York.

PLANNING

Harold F. Smiddy * | General Electric Company

They also neglect one of the major responsibilities of leadership. Each of us has an obligation to provide continuity to this process of development which will help assure that the legacy we leave behind us is something more than the inheritance provided for us.

Certainly there is a need for a philosophy of manager development because it is nothing more nor less than a fine-sounding name for the most practical kind of thinking about the needs—present as well as future—of your own company for the maximum amount and kind of competent managing you need to meet and satisfy the demands placed upon you by your customers, employees, owners, suppliers, and the public speaking through its representatives in government. You need it because it will help you simplify the problems of managerial manpower planning; and because it will, if it is a sound and thorough philosophy, help assure you of maintaining a steady pattern of corporate growth.

The heart of the matter is "managerial maturity." Such maturity can be achieved—or, more properly, we only know we are achieving it—when we can measure its effects in terms of results. It is a maturity, furthermore, which can be expressed and demonstrated only by the attitudes, knowledge, and actions of individual people working in a team effort in a way which produces a characteristic, or over-all, corporate maturity. It is clear, I think, that we understand "managerial maturity" in a full and usable way only when we clarify our picture of the manager himself as a mature man in a complicated world.

Study of the Work of Managing

All businesses have certain things in common regardless of size or product, and these stem from the fact that all of us, by and large, work for managers and work at managing. In telling you about General Electric's approach to manager development, I am fully confident that what I say will have a large measure of application to a business of any size, because it has been predicated upon and designed to fit the decentralization pattern which has made "small company" operation a way of life within the actual specific businesses of General Electric Company.

In our company there was a realization that, if decentralization was to become a fact, and if authority and responsibility were to be placed as close to the scene of action as possible, we would need many, many competent managers. There was, therefore, a need to make a penetrating study of how men could be equipped to accept authority and assume responsibility. Mr. Cordiner, the president of General Electric, pinpointed for us the importance of the problem, when he warned, "Not customers, not products, not plants, not money, but managers may be the limit on General Electric's growth."

We instituted a full-dress investigation of the work of managing, studying not only our own company but also many other companies and organizations, as well as the seemingly endless literature and writings which have been produced since the beginnings of the first "industrial revolution." Out of it, we have come to a clearer understanding of the manager and his work, and from it we have chosen the approach which seems to be most suited to the development of men into managers of the quality and quantity our future requires.

Managing Is Professional Work

It is amazing to think how many years it took for people to become fully aware of the fact that managing is a professional kind of work. The engineer, the designer, the accountant, the salesman—all have received a special sort of education to equip them for their special kind of work. Yet, we somehow assumed that you could make a manager by simply throwing the job at the man.

Experience indicates that far too often this simply isn't true, and that managing itself is, in fact, a scientific kind of work which requires knowledge and understanding of a set of basic principles. Most important, we know that these principles, like the principles of any science, can be learned and can be taught. They must be the subject of a steady, conscious, deliberate, and determined study on the part of each individual, coupled with a willingness to look at the familiar in a new light and from an unfamiliar angle.

Objectives of Manager Development

The objectives which have been set at General Electric for the manager development activity are four in number. Although they are not easy to attain, they are definitely not beyond our abilities. Above all, they are practical and realistic objectives which are voluntarily accepted by the members of our managerial teams as they come to a realization of their own need to increase personal effectiveness and performance on the job. These objectives are:

(1) To provide all managers and potential managers with challenges and opportunities for maximum self-development on their present jobs and for advancement as earned.

(2) To work toward improving skill and competence throughout the entire manager group so as to help managers become equal to the demands of tomorrow's management job.

(3) To operate to furnish the company with both the number and kind of managers which will be needed in the years ahead.

(4) To encourage systematic habits and procedures to make it simpler for each manager to discharge his manager development responsibility.

This approach consists not of one plan, but actually of as many "plans" as there are individual managers; because it is each individual manager who has the dual responsibility, first, for his personal development, and, second, for the creation of the best possible "managerial climate" in his own organizational component for those men who report to him. He can forget neither the importance of his own progress, nor his responsibility to encourage along similar paths those whose work he manages.

Four-Part Manager Development Approach

After considerable research, testing, and study, General Electric boiled the many possibilities down into an approach which consists of four major parts. They are the managerial climate of the organizational component, self-development planning, manager manpower planning, and manager education.

THE MANAGERIAL CLIMATE

In any manager development program, the first thing which must be reviewed and analyzed is the managerial climate of the organizational component. The climate is created by the manager—his attitudes and behavior, policies

* Mr. Smiddy is Vice President, Management Consultation Services, General Electric Company, New York, N. Y.

and practices, communication between himself and those whose work he manages, and the standards for such a "climate" which he sets.

Analyzing an organization's climate thoroughly is a painstaking and difficult task. All of us are able to sense the attitudes of the people around us, but it is sometimes far more difficult to understand "reasons why" for such attitudes. And yet, to capitalize on those that are good, and to change those that are bad, cannot be done with any degree of reliable or repeatable success until such reasons are fully and accurately known.

You will, then, need more in your approach than a set of good ideas. You will need the climate in which those ideas will be accepted voluntarily—almost, in fact, demanded of you—and in which they can grow into habits and behavior which result in materially improved performance for the enterprise and vastly increased job satisfactions for the individual.

SELF-DEVELOPMENT PLANNING

Self-development planning is the second fundamental of the General Electric approach. It is personal, and it is direct, for every manager is responsible, first, for his own self-development, and second, for providing both opportunities and challenges to all the men whose work he manages.

There is only one basic way self-development planning can be made a reality. The manager must actually sit down and make a careful and detailed appraisal of each man reporting to him, and then build with that man a personal plan of development based on his demonstrated particular needs, qualifications, and potential.

The secret of success here is to throw away those single-page "lick and promise" appraisal sheets that have really outlived their usefulness, and work out a comprehensive plan with each man, as an individual. You will find that you need to do it literally man by man, manager by manager, and component by component throughout your company.

MANAGER MANPOWER PLANNING

The third part of the approach consists of orderly manager manpower planning. This work is divided into three distinct, though interlocking, phases:

(1) Long-range planning which looks ahead at least five years to determine the size and kind of organization which will be needed to cope with the conditions and achieve the objectives of that time.

(2) Short-range planning which focuses on the specific needs of the next eighteen months to provide for orderly filling of vacancies and for proper promotion and placement of men.

(3) Planning for continuity of managerial leadership in order to assure the life and continuity of the enterprise itself.

This phase of the approach is undoubtedly familiar to those who have been planning for their company beyond the opening of the doors in the morning. Perhaps I have introduced a difference in emphasis, however, with the principle that no planning has sufficient value or meaning unless it includes provision for effective managing of that plan; and that no future can be counted on unless it is built on the quality of the men who will bring it into being.

MANAGER EDUCATION

The fourth and last phase of General Electric's approach to manager development is a manager education program. We are using four elements or techniques in our educational program, but I will describe in detail only the three which I believe can be put into use in any organization with little loss of time and at very small expense.

The first elements in this program are the individual reading and study plans. The basic concept of manager development is that it is an adult educational process. It follows, therefore, that development is first and foremost the responsibility of the individual himself. These plans are highly flexible and can be worked out specifically for each manager or potential manager by his own manager in the course of the self-development planning appraisal process.

The wide latitudes inherent in individual reading and study plans allow individuals to direct the course of their self-development into those channels of the organization and managing sciences which are most suited to an orderly advance in knowledge and understanding.

One of the most striking things that has come out of the studies into the ways adults learn most rapidly and most effectively is that education requires the acquisition of two kinds of knowledge. The first is the knowledge of experience which can come, of course, only from the doing and observing of a body of work. The second, the knowledge of reason, comes from the reading and discussion of the ideas and the experiences of others. Integrating the second with the first is the only possible, and really the only practical, way of understanding both how to do things and why the things should best be done that way and at that time. When these two kinds of learnings are properly integrated, there is an insurance provided to facilitate "inventing upwards" and against rediscovering principles which are already proved and available—against the need for each generation, so to speak, to reinvent the wheel.

The second part of manager education is the installation in plants and offices of a professional business management course. Here, the cross-fertilization process which multiplies understanding can be made available to those who are engaged in the individual reading and study plans.

In planning to institute a course of this sort, careful consideration should be given to the method of running the course. At General Electric there seems to be an overwhelming preference among the participants in adult educational groups for conferences where intimate personal participation and the free expression of ideas are encouraged.

Yet, a word of caution is in order. You will probably find that unless some expert knowledge of a subject is brought to the meeting by its chairman or leader, together with an intention to gain better understanding during the sessions, the advance of knowledge for the participants is slow and sometimes impossible. To prevent "spinning your wheels," there needs to be, therefore, along with functional kinds of knowledge, a strong leadership, a set of clearly stated and universally understood objectives, and a basic enthusiasm for the course itself.

The important thing is not so much the specific subjects you choose—for the students will speedily change those to fit their needs—as it is the creation of a favorable and encouraging managerial climate in which a professional business management course can be brought into being. As managers, it will be better if your kick-off words are "Let's do it" rather than merely, "Go ahead and do it if you want."

The third phase of manager education is concerned with outside management courses and activities. There are very few industries anywhere in the United States which are isolated completely from the facilities of professional groups and institutions of learning. Many companies are sponsoring extension courses available from universities and conducted at the plant or office location. Many other companies are sending their men to such schools as Northwestern, Harvard Business, M.I.T., Columbia, Carnegie, Syracuse, Stanford, and Wharton, among others, as a means of bringing into the company the knowledge of managing and organization being developed on business frontiers throughout the free world.

This third phase of the manager education plan should include the encouragement of sensible participation in the affairs of such outside organizations as professional societies, community and

civic groups, and similar activities which can contribute significantly to the self-development of the individual.

These three phases—individual reading and study plans, professional business management courses, and participation in outside management courses and activities—are the key ideas of General Electric's approach to manager education.

I do want to refer to the fourth phase of our approach, although I believe that its application is necessarily limited to those companies whose manager manpower requirements are very large. It is an Advanced Management Course which is given by General Electric in an uninterrupted 13-week period of concentrated study at the company's Management Research and Development Institute. We look forward to four such sessions each year, and will develop the managerial skills of 300 men from various levels of General Electric's managerial team in this time.

Playing by Ear

I believe that you should not, and really cannot, avoid the necessity of planning an approach to your own manager development which is designed to fit the needs of your own enterprise precisely.

We have come to realize, in the course of our business history, that progress and profits come only to those who, in the long run, satisfy the public good. Our advances in technology have created an endless ramification of technical knowledge—in a sense of the "how" part of what we do—but it is becoming increasingly necessary that we devote a larger measure of our creative planning to the "why" part of our work.

People at large are becoming more sensitive to business and industry as a force as well as a producer in our economy. What you do and how well you do it are but part of the demonstration of your citizenship responsibilities as a corporation. And, it depends inevitably on the kind of managers you will develop.

Managing by intuition and inspiration is a luxury we can no longer enjoy or afford. The simple facts of life are that the decision-making work of a manager now affects so many other people and involves such enormous capital investment and risk, that "playing it by ear" can no longer be justified.

Teamwork, the all-important cement that joins our highly specialized industries and workers within industry into a productive whole, can be left to chance no more than can the winning of football games be left to the unguided resourcefulness and instinctive co-operation of individuals who must play without a quarterback.

The science of managing is neither a toy of the college professor nor an armchair diversion for the business executive. It is a way of survival for the business you are in, and it is a way of increasing—immeasurably, I believe—your ability to contribute to the progress of people everywhere, no less than to the growth, profits, and competitive leadership of your own enterprise.

It is, finally, a way in which you can see within yourself an awakening of a new awareness of the importance and meaning of your work, and a corresponding reward to yourself in terms of a job you can handle with progressively greater and lasting skill and satisfaction.

OFF THE CUFF

The following are capsule excerpts from Mr. Smiddy's replies to specific questions during the discussion period following his Lake Placid address.

TESTING: Tests have a definite and positive place in personnel and management development, but they are often better for screening out than for assuring the definite success of an individual.

PERIODIC APPRAISAL: Every manager should, at least once a year, compare what his men are doing and how they are performing against the job description and the specifications for the men. In many cases, the man is given the same outline and asked to do it himself. The essence is in sitting down in a climate of mutual confidence and actually going over the problems with the men concerned.

JOB ROTATION: We try to do it only where it is necessary for a rather quick brushup of a man whose opportunity to broaden has come but whose experience has been narrow. To substitute for it, we have been decentralizing so that the man in any function is in intimate contact with the rest of the team. We do not do much in the way of putting observers around the place watching other folks work.

ASSISTANTS: We are against assistants as a way of relieving loads on managers. The way to train men to be managers is to make managers of them, not observers. Give them a manager's job of their own at a lower level in the organization and let them make their own mistakes before there are six or seven ciphers tied onto them. We don't have any coordinators either: a coordinator is a third party with a vested interest in keeping two people apart that you're paying to work together.

COMMITTEES: Most committees become devices for backscratching, politics playing, and reducing decisions to the lowest common denominator of the most timid soul among its members. We use committees to get views on a question, but not to make decisions, because the decision is still the responsibility of the fellow who would have to make it if he were not in a committee meeting.

JOB EVALUATION: Job evaluation on a company-wide basis is an aid to orderly judgment and an assurance that there is a systematic way of covering all the factors, but it is not a precise tool and each department is left free to use what method it wants. The test of whether such a program is working comes when promotion opportunity from one function to another arises and whether such promotions can be worked up.

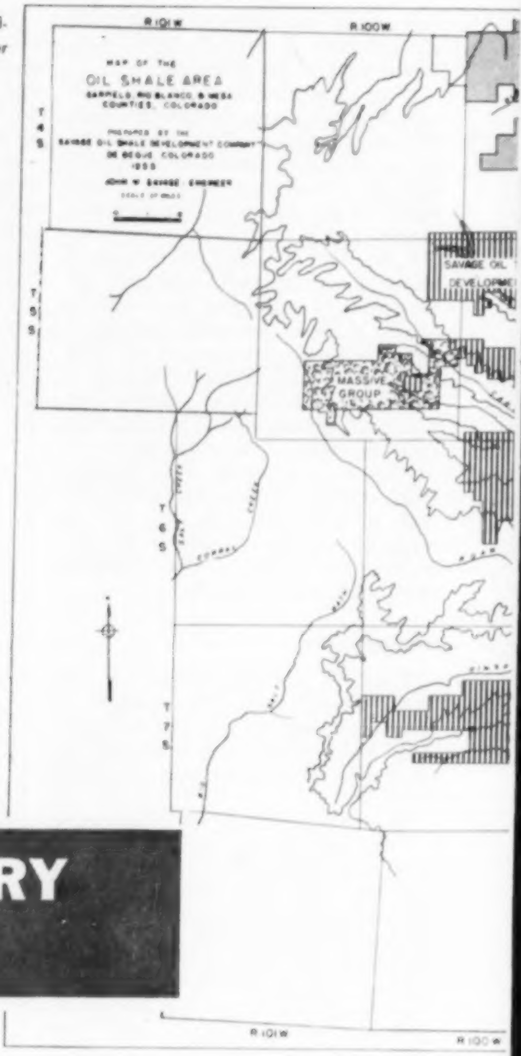
SPECIALISTS: In the case of specialists who would not make good managers, we consider that there are parallel paths to promotion in the company: one by the route of the individual contributor or specialist, the other by the route of manager. If we need a specialist in a particular field at some point in the organization, we have no objection to paying him more than his manager of the moment since the manager can advance to a higher managerial job somewhere, while the specialist's whole career may be spent at that point.

RESPONSIBILITY-AUTHORITY: Our philosophy on authority is that we don't delegate it at all; we reserve it. The authority in a job is complete to do the job unless in advance in writing we take some of it away.

DECENTRALIZATION: Everybody likes decentralization down to himself. He thinks it perfectly wonderful when the boss lets him in on the know, gives him a lot of rope, trusts him, puts his confidence in him. He says, "Boy, that's the way to operate." And then you say, "Joe, what are you doing with this fellow under you?" Well, he isn't quite ready. He's just a little young . . . hasn't had quite enough experience . . . might make a mistake. We have made progress in solving this problem by giving the manager enough people to look over so that he can't get his nose too far into any one of their businesses.

The basic thing is to get a full-time job for the manager doing his managing rather than doing his people's work.

Fig. 1. Major U. S. oil-shale properties under private ownership.



The United States shale-oil industry will be based on the utilization of the 500 billion barrels of proven oil reserves existing in 2 million acres of oil-shale deposits in northwestern Colorado and in adjoining Utah and Wyoming.

The most commercially feasible shale area for initial development is the 1,000 sq. miles of the Mahogany Ledge in northwestern Colorado, where a 100-ft. thick measure of the deposits, averaging 25 gal. of oil/ton of shale, presents a known mineable reserve of 125 billion barrels of oil. This reserve alone is equivalent to 50 years of domestic petroleum production at 1955 rates.

According to one opinion (4), "no further finding costs are necessary nor is there any uncertainty about the location and magnitude of the supply." This is important when it is considered that at present $1.25/bbl. finding cost for new petroleum, the above Colorado deposits alone represent an immediate saving of more than 150 billion dollars in the cost of new oil exploration. This figure, calculated at present costs, is certain to continue to increase as it has so substantially in recent years.

A SHALE-OIL INDUSTRY is on its way

Charles H. Prien,

Denver Research Institute
University of Denver
Denver, Colorado

and

John W. Savage

Savage Oil Shale Development Company,
Debeque, Colorado

It might well be argued that the petroleum industry could wisely afford to spend as little as 1% of its present cost of exploration per barrel of new oil on development of an oil-shale industry. Even this small percentage would provide 1.5 billion dollars for this purpose if allocated on the basis of the shale reserves which could thus be made commercially productive.

Union Oil Co. officials' faith in the commercial future of oil-shale processing led in 1955 to the initiation of a $5,000,000 pilot plant construction program near Grand Valley, Colorado. With a capacity stated to be 1,000 tons of shale/day, this plant will test Union's retort design and give more accurate cost figures. These latter may confirm Union's belief that oil from shale can be produced much cheaper than new well-oil can be found.

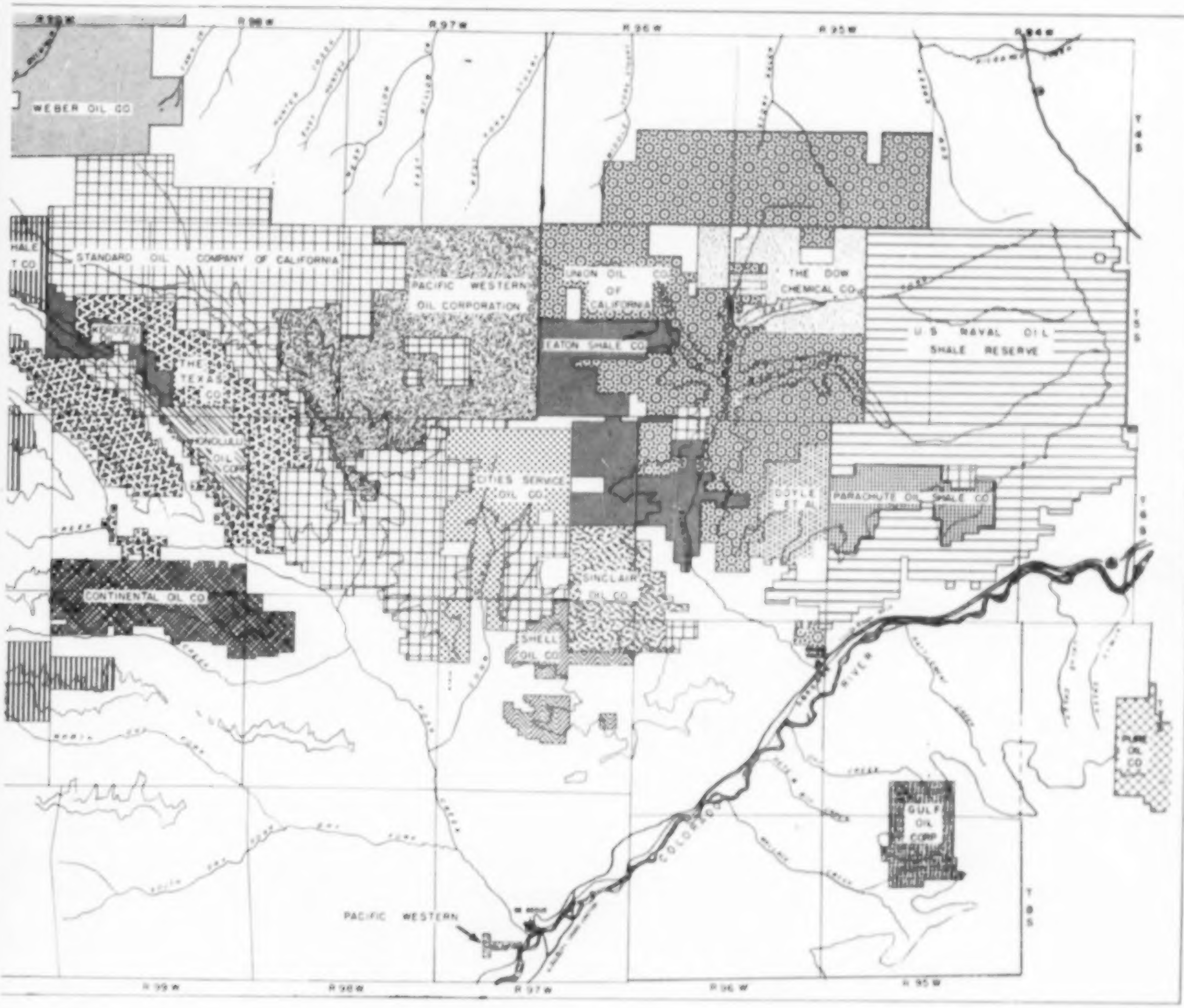
For the past two years Sinclair Oil Company has conducted field tests at its own properties, using several methods of "retorting" oil shale in the deposit through controlled underground combustion. The outcome of these experiments has not been published. The geologic nature of the strata may present formidable problems. Costs, however, might be equal to or less than those attainable by mining and the use of above-ground retorts.

Who Owns the Oil-shale Deposits?

It was not until World War I that interest was aroused in the important oil-shale deposits of the Western United States. Between 1916 and 1920 some 20,000 placer-mining claims were filed on nearly all the oil-shale land in Colorado, Wyoming, and Utah.

The Leasing Act of 1920 withdrew public deposits of oil shale from further locations and placed it under the general land-leasing law with oil and gas. Although vacant public land is, under certain conditions, still available under this act, companies planning to produce shale oil find it desirable to own their land and avoid the difficulties of the leasing act.

The placer-mining claims which were valid when the Leasing Act was passed are still valid. Nearly 100,000 acres of these oil-shale claims have gone to patent in the last five years. It is perti-



nent here to review briefly the activities of some major petroleum companies and their shale land purchases (patenting).

Petroleum Companies and Their Buying Activities

The Union Oil Company of California started buying oil-shale land in 1921. In the next few years Pure, Continental, Standard Oil of New Jersey, Prairie Oil and Gas Company, Ventura Oil Company, and Honolulu Oil Company bought blocks of shale land. During the 1930's Standard Oil Company of New Jersey sold its shale land. (It was later bought by Standard Oil Company of California). The Texas Company acquired 10,000 acres of shale when it bought the Ventura Oil Company, and Sinclair Oil and Gas Company acquired 7,000 acres when it absorbed the Prairie Oil and Gas Company.

The end of World War II found only four large oil companies owning substantial blocks of shale property. In 1946 Standard Oil Company of California leased 12,000 acres of shale land from a private group. The difficulties of lease terms made it more desirable later to purchase this land outright. Soon Union Oil Company of California began to add to its 20,000-acre block on Parachute Creek. In 1948 Pacific Western Oil Corporation of Los Angeles contracted for 22,000 acres of choice land. These cost about $30/acre, about the same as Union had paid in 1921.

During the next two years Union added more than 10,000 acres to its holdings at costs up to $50/acre. Cities Service and Shell began to build blocks of land in 1951 and paid $50 to $60/acre. In 1952, Gulf Oil Corporation contracted for 4,000 acres, and The Texas Company added 7,000 acres to its 10,000-acre block. Some 60,000 acres of land were patented in 1952 alone. Union Oil Company has continued to maintain a dominant position, building its holdings in recent years to nearly 50,000 acres, at prices up to $100/acre. Standard Oil of California has purchased additional land in several areas, sometimes paying more than $100/acre. With recent acquisitions Standard's holdings, now well over 50,000 acres, places the company in an equally dominant position with Union Oil. Within the past two years Dow Chemical acquired control of the Columbia Oil Shale and Refining Company which owns 8,000 acres of the best shale land. Dow is thus the first major chemical company to acquire shale land.

It is obvious from the above that interest in oil shale has increased markedly during the past ten years. The price of land has correspondingly increased. Some land is known to have been sold for more than $300/acre. However, this is still equivalent to a little more than 500 bbl. of reserve for each dollar paid, certainly a reasonable investment.

In 1954 Standard Oil (California) completed a $100,000 survey and mapping project of its widespread holdings. Other companies have acquired water rights and plant space, and have engaged in planning for access roads and mining sites. The Union Oil Company has recently purchased 3,000 acres of ranch land near Grand Valley for plant working space. Eaton Shale Company has similarly acquired 2,000 acres, and Standard of California and Pacific Western each have about 1,500

acres near Debeque, Colorado. The Texas Company has nearly 2,500 acres of ranch land with its property.

The accompanying map (Figure 1) and also (Table 1) show the location and reserves of most of the major holdings in the active oil-shale area of Colorado. Patented and unpatented land as well as ranch lands are included. Holdings by individuals and subsidiary companies have been grouped under names which are most familiar.

The area shown, in Garfield County, Colorado, lies 200 miles west of Denver and 30 miles east of Grand Junction, Colorado. The rich oil shale outcrops in 30 miles of bold escarpment 3,000 ft. above the Colorado River. Much of the deposit is plainly visible from the Denver & Rio Grande Railroad and transcontinental highways. The tributaries to the Colorado River add an additional 600 miles of escarpment as potential working faces. This escarpment is shown as a continuous wavy line on Figure 1.

Mining and Crushing Oil Shale

In most places the working zones of oil shale are covered by several hundred feet of overburden and open faces are necessary for cheap mining. A few favorable areas are amenable to open cut mining. The U. S. Bureau of Mines has conducted commendable research on cheap methods of underground room and pillar mining for more than ten years at the Naval Reserve near Rifle, Colorado. As a result it is now possible to mine shale for approximately 50 cents/ton, fixed costs included. This is equivalent to about 85 cents/bbl. oil. Further research could reduce this cost, the Bureau feels, to around 30 cents/ton (50 cents/bbl.).

A figure of 30 cents/ton represents a saving of approximately 35 cents/bbl. Since mining costs are so substantial a proportion (one third) of the cost of final, partially refined shale oil (see Table 2), it is obvious that further work to reduce these costs should be rewarding. For this reason it is desirable that Congressional support continue to be given this mining research. It is difficult to understand in what other way realistic and practical oil-shale-mining research could be conducted, except in a demonstration mine of the type which has been created and operated at Rifle by the Bureau.

The crushing of shale at present employs both primary and secondary gyratory crushers. It is no problem as long as sizes in the range of 1 to 3 in. maximum diam., can be fed to the retort. Such sizes are acceptable to the

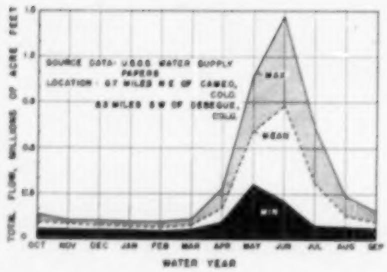


Fig. 2. Maximum, minimum, and mean total monthly flow of Colorado River near Debeque, Colorado (1934-1949).

Union retort and to the U. S. Bureau of Mines gas-combustion retort. For smaller shale, however, crushing costs increase rapidly. For example:

> To produce 1-in diam. shale, the over-all crushing cost is about 10 cents/ton (16 cents/bbl. oil); — 4- to 8-mesh shale costs 25 cents/ton (42 cents/bbl.); for — 14-mesh shale-crushing cost is about 29 cents/ton (nearly 50 cents/bbl. oil).

It is important to keep these figures in mind, particularly when one is considering retorting processes wherein smaller sized shale is being utilized to increase heat transfer rate, e.g., fluidized retorting.

Water for an Oil-shale Industry

The water situation in the shale country is as follows: first the area is a semiarid region with an annual rainfall of 9 to 13 in., and evaporation rates of 90 in./yr. The region is served by the Colorado River and its tributary creeks, from which all water for mining, retorting, and partial refining must be drawn.

The Paley Report forecast a production of 2 million barrels of shale oil daily by 1975. With acceptance of this figure for the moment and with the use of the National Petroleum Council's estimates of water requirements for oil-shale processing, calculations indicate that it will be necessary to divert 450,000 acre-ft. of water/yr. from the Colorado River. Some 150,000 acre-ft., however, can be returned subsequently to the stream. Net industrial and domestic consumptive requirements are therefore 300,000 acre-ft./yr. (267 million gal./day).

The mean monthly flow of the Colorado River in the vicinity of the shale deposits is shown in Figure 2. It is to be noted that some 3 million total acre-ft. of water flow by the oil-shale area each year, but that seasonal flow fluctuates widely. Adequate storage would therefore have to be provided. The Upper Colorado Storage Bill presented to the recent session of Congress is a step forward providing for such storage dams and reservoirs.

It is estimated that a full-scale industry will require storage for a supply of 265 days, and that direct flow can be taken during the 100-day period when river flow is high. Storage reservoir design must make adequate allowance for the high evaporation rates previously mentioned. Impounding of water in underground reservoirs by the well-known infiltration technique might be a partial answer to the high evaporation rates, at least at or near plant sites. Plastic microspheres covering surface reservoirs are also a possibility.

Water rights of high priority, primarily for agricultural use, have already appropriated 1,160,000 acre-ft./yr. Even allowing for these, however, the flow of the Colorado River is adequate to provide water for a 2 million barrel/day oil-shale industry, assuming adequate storage.

Location of Process Facilities

The shale retorts, as pointed out by the N.P.C. report (*3*), will probably be placed at the mine sites, located in most cases several thousand feet above the valley and canyon floors. This will facilitate dumping of the spent shale, after removal of its 10 to 20% organic content, into the neighboring deep canyons. It is possible also to consider returning spent shale as mine-fill.

A cursory examination of a topographic map of the region would indicate that ample canyon space exists for cheap disposal of spent shale for many years, even from a 2-million barrel/day industry. Careful planning can insure proper access and prevent erosion by wind and by runoff. Tests indicate that no problems in leaching of harmful constituents need be expected.

Complete refining of this shale oil to end-fuels in Colorado is neither economically nor technically feasible. From an economic viewpoint there is not sufficient market nearby for the products. From a technical point of view insufficient water is available. Since the oil is not suitable in its raw state as a pipeline crude, the approach is therefore to refine the material partially so as to produce a suitable pipeline crude, transport to the marketing area (e.g., Los Angeles), and complete refining at the latter place.

Two series of particle-refining operations have been proposed for accom-

plishment at the mining area, prior to transporting product to the West Coast by pipeline. In the first case, as proposed in part by the Union Oil Company (and used in the National Petroleum Council's study), the following operations are conducted in Colorado:

The shale oil is coked, and the resulting gasoline fraction catalytically reformed. Higher boiling coke distillate is hydrogenated to remove sulfur and nitrogen and partially saturate olefins present. The hydrogen sulfide and ammonia produced are recovered. The gasoline fractions so obtained by hydrocracking is sent to the above-mentioned catalytic reforming unit. The remaining hydrogenated liquid product is hydrogenated diesel fuel. Hydrogen for the process is obtained by the steam-methane reaction by the use of refinery gas from the coking unit. The raw catalytic reformed gasoline and hydrogenated diesel stocks are sent via pipeline to Los Angeles for finishing by conventional refinery processing.

In the Bureau of Mines process the raw shale oil is submitted to a visbreaking treatment (gas loss 2-6%), and thence sent to Los Angeles for refining by conventional recycle thermal cracking, catalytic reforming, and acid treatment of gasoline stock, to produce gasoline and heavy fuel oil as the main products.

Economic studies of each approach, based on 1951 cost data, indicated that the wholesale gasoline selling price at Los Angeles would be approximately the same (14.7 cents/gal., based on 6% return on investment after taxes). This figure is to be compared to a 1951 wholesale gasoline price in Los Angeles of 12 cents/gal. Current wholesale price of petroleum gasoline is well over 13 cents/gal. Since production costs of shale gasoline have not risen proportionately, the processing of oil shale is now even more favorable.

Partial refining (e.g., visbreaking) of the shale oil produced will be carried on at sites in the valleys below the mine, or at the Colorado River, a few miles away. By-product manufacture and related industries will be substantial. A 2-million barrel/day industry, for example, will produce (in Colorado) 3,700 tons of ammonia, 1,700 tons of sulfur, 47,000 tons of coke, and one billion cubic feet of refinery gas (1,000 B.t.u./cu.ft.). The last mentioned is equivalent to 60 to 70 million kw.hr. of power. Population estimates for such an industry vary from 100,000 to 750,000 for the working force alone, including families and supporting community personnel. Present population of the area is only a few thousand.

All these plants will require large areas. The refineries alone, for example, by N.P.C. estimates, will need more than 1,100 acres. Recognizing this, the companies owning oil-shale properties are already diligently acquiring additional bottom-land for plant sites, as previously noted.

After the initial partial refining in Colorado to make a pipeline crude has been accomplished, the resulting products will be transported by pipeline to market, either on the West Coast or in the Midwest. The Los Angeles area, some 800 miles away, appears to be the most favorable outlet. At pipeline terminal final refining to end-products will be undertaken. The products, from a 2-million barrel/day industry, will include 1 million barrels of gasoline (regular and premium grade), 500,000 bbl. diesel fuel, 70,000 bbl. liquid petroleum gas (L.P.G.), and 24,000 bbl. fuel oil. Their production is discussed more fully below.

Nature of Oil Shale

In order to understand the retorting of oil shale, it is first necessary to present a brief description of the chemical nature of this raw material. In Colorado oil shale organic material is present from a trace to 30% by weight (avg., 6-12%), corresponding to 10.5 to 80 gal. derived shale oil/ton, in a laminated, calcareous inorganic matrix. This matrix or rock, by analysis approximately 48% silica, 17% alumina and iron oxides, 28% calcium and magnesium oxides, is principally of calcite, dolomite, and clay, with quartz, feldspar, and pyrite as minor minerals (*1*).

The organic matter in Colorado oil shale, sometimes called kerogen, is a high-molecular weight substance of largely unknown chemical structure. In semipure form it is a brown amorphous powder, with a carbon/hydrogen weight ratio of approximately 7.3, and resembles powdered, decayed leaf mold in appearance. It contains roughly 2.6% nitrogen, 1.3% sulfur and 9.5% oxygen. Chemically it is probably a nonbenzenoid, polycyclic substance loosely interconnected through hetero side chains. An approximate empirical formula might be given as $C_{[illegible]}H_{[illegible]}O_{11}N_{4.4}S$. It is noted

Table 1.—Size and Reserves of Major Colorado Oil Shale Properties

Owner	Total size (acres)	Shale bearing area (acres)	Reserves of shale oil * thousands of barrels
Cities Service Oil	10,000	7,100	1,480,000
Continental Oil	10,800	3,600	270,000
Dow Chemical	8,500	7,900	2,312,000
Doyle, *et al.*	4,400	3,400	761,000
Eaton Shale	14,700	9,000	1,933,000
Gulf Oil	3,700	1,600	133,000
Honolulu Oil	3,300	1,500	205,000
Kerogen Oil	2,300	1,400	196,000
Massive Group	4,400	2,400	118,000
Pacific Western Oil	21,900	17,800	4,186,000
Parachute Oil Shale	5,900	4,900	830,000
Pure Oil	3,800	1,000	20,000
Savage Oil Shale Development	18,700	9,700	903,000
Shell Oil	4,200	1,700	255,000
Sinclair Oil & Gas	7,300	4,700	876,000
Standard Oil Company (Calif.)	53,900	41,000	7,198,000
Texas Company	18,700	14,000	1,626,000
Union Oil Company of Calif.	47,300	38,700	8,510,000
Weber Oil (General Petroleum)	24,600	23,000	4,000,000
U. S. Naval Reserve	38,700	31,700	5,000,000

* From the mineable section yielding 25 gal. oil/ton shale. Recoverable reserves may be 35% less from mining, crushing, and retorting losses.

Table 2.—Approximate Distribution of Costs in Oil-shale Processing

Basis: 250,000 bbl./day operation yielding 200,000 bbl. partially refined products in California. N.P.C. and Bureau of Mines data used for estimates. Depreciation and return on investment included.

	Cost, dollars per barrel partially refined shale oil products in California
Mining	$0.90
Crushing	$0.15
Retorting	$0.45
Partial refining in Colorado	$0.95
Pipeline transportation	$0.20
Cost of partially refined shale oil in California	$2.65

Note: The above are order of magnitude figures only. It is assumed that catalytically reformed gasoline and hydrogenated diesel stocks are the forms in which the partially refined shale oil are furnished to California market.

that there are 1.66 hydrogen atoms for each carbon atom present. This organic substance is essentially insoluble in common petroleum solvents at room temperature.

The chemical relationship between the organic and inorganic matter is unknown although some evidence of coordinated porphyrin iron and nickel complexes between the two has recently been found by the Denver Research Institute. The role of the nitrogen, sulfur, and oxygen hetero atoms in the structure is also incompletely understood. Evidence of at least two forms of kerogen has been discovered, each with its own rate of decomposition, and each varying in relative proportions of C, H, N, S, and O present.

It is from this complex organic substance that the liquid hydrocarbon mixture, called shale oil, is formed. The process employed and the only successful one to date, is that of destructive pyrolysis of the dry, crushed oil shale at temperatures in the order of 900° F. The resulting shale oil, with a C/H ratio of approximately 7.2 to 7.5, a nitrogen content of 1.8%, and a sulfur content of 0.8%, consists of 39% hydrocarbons (many highly unsaturated) and 61% carbon-hydrogen compounds containing oxygen, nitrogen, or sulfur. It contains less than 3% straight-run gasoline fraction. Only one half of the total oil is distillable below 300° C. (572° F.) at 40-mm. pressure. It is thus intermediate between petroleum crude (C/H of 6 to 7) and coal pyrolytic products (C/H of 10 to 16) in character.

Shale Retorting

Over 2,000 retort designs have been patented to carry out this pyrolysis. Heat, in these designs, is furnished either externally through retaining walls or internally by contact with hot gases or liquids. Combustion of residual carbon on the retorted shale may be used to furnish the temperatures required. In the United States retorting of the oil shale in its underground deposits has been attempted, by the use of both combustion and electrical heating.

The most successful retort designs to date in the United States have been essentially vertical vessels of circular cross-section, internally heated by hot, recycled gases, or flue gases obtained from combustion of residual carbon on previously retorted shale. Crushed shale is moved either downward or upward through the vessel, countercurrent to the hot gases. Both combustion and retorting zones exist in the same vessel.

Heat transfer rates in these retorts are estimated to be in the order of 100-200 B.t.u./(hr.)(° F.)(cu.ft. of shale bed). Shale throughput rates are in the order of 135 to 300 lb./(hr.)(sq.ft. of retort cross-section). These values are substantially the same range as obtained in Scotland's Pumpherston retorts, which have been in use for 100 years. Shale particle sizes, in order to keep crushing costs within reasonable limits, are fairly large. The Bureau of Mines gas-combustion retort uses $+\frac{1}{4}$ to $-3\frac{1}{2}$ in. shale, the Union retort −3-in. shale.

Shale-oil yields in both the above retorts are in the order of 90-95% of Fisher assay. This corresponds to a conversion of roughly 60-65% of organic matter to useful shale oil, 10% to gas (average heating value 80-100 B.t.u./cu.ft.), and 25% to carbonaceous residue on the spent shale. The retort off-gas is partially recycled and burned in the combustion zone of the Bureau's retort, where the carbonaceous residue on the spent shale is also burned. These two sources supply the over-all heat for the retorting process. In the Union retort combustion of residual carbon on spent shale is used as the sole source of heat for pyrolysis. Excess retort gas is used to supply heat and power requirements for mining, retorting, and partial refining in Colorado. Both retorts utilize incoming cold shale to condense partially the oil vapors formed, thus reducing cooling water requirements to a minimum.

Residence time in the retorting zone of either the gas combustion or the Union retort is in the order of 45 min. to 1 hr. Estimation of decomposition time of the organic matter from kinetic data in the temperature range of the retorting zone indicates that only a few minutes (perhaps as high as 10 min.) should be required for conversion to gas, oil, and bitumen. The obvious limiting factor, therefore, is primarily the heat transfer rates from gas to solid particle which are attainable.

The heat transfer rates are functions of the temperatures employed, the particle sizes involved, and of the medium (gas-solid system), e.g., gas velocity. It follows that, theoretically, small particles of shale exposed to high temperatures at high gas velocities are desirable. A fluidized system meets these requirements.

Many factors, however, act to limit conditions of ideal heat transfer. For example, crushing costs, as previously noted, increase rapidly as shale particle size is reduced to 4-mesh and below. As solid temperatures are raised above 1,000° F., mineral carbonate decomposition becomes substantial thus increasing the nonproductive consumption of heat. Coking of crushed shale from certain of the richer shale strata, with consequent disturbance of both gas and solid flow rates, also occurs.

The degree of cracking, character of the oil produced, and amount of gas produced are all temperature dependent. In the case of the Bureau's gas-combustion process, the production of a stable aerosol oil condensate capable of removal from the retort is also a function of temperature. Such factors as the above, and others (e.g., economical heat balance around the retort) now require operating conditions which are necessarily a compromise with ideality.

The matters of both economical heat consumption in the retorting process, and minimum water consumption for vapor condensation are important process considerations. The former is a prerequisite to keep retort operating costs at a minimum. The latter (minimum water consumption) is dictated by the limited water availability in the shale region. Both the Bureau and the Union retorts provide engineering designs which are the best compromise solutions to date to the above problems.

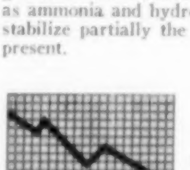
Since retorting costs are a significant proportion of the total cost of oil-shale processing (see Table 2), additional retorting research and development can contribute appreciably to reducing the cost of oil-shale processing.

Shale-oil Refining

The shale oil produced by either the retorts of the Union Oil Company or U. S. Bureau of Mines is a highly viscous, waxy substance of about 20° A.P.I. gravity and a pour point of 90° F.

Only 50% is distillable below 300° C. at 40-mm. pressure. There is less than 3% of straight-run gasoline fraction present. Olefinic content is high (more than 40% of the naphtha fraction).

The oils contain 0.7-0.8% S, 1.6-2.2% N, and 1.5-2%O. The high nitrogen content is particularly significant since its presence precludes the use of catalytic-cracking techniques. Catalytic desulfurization also is less applicable. Mild hydrogenation will remove nitrogen and sulfur as ammonia and hydrogen sulfide, and will stabilize partially the more reactive olefins present.



Economics

An approximate distribution of costs in producing partially refined shale oil, in accordance with the 1951 N.P.C. estimates, is shown in Table 2. The total \$2.65/bbl. shown is the cost of laying down raw catalytic reformed gasoline and hydrogenated diesel stocks at the

Los Angeles terminus of a pipeline. The N.P.C. figures from which the data, for the most part, were calculated assume Bureau of Mines room-and-pillar mining, Union Oil Company retorting, and the coking-hydrogenation refining process set forth above.

The 1951 price of 27° A.P.I. petroleum crude California was $2.40/bbl. Using this last figure and allowing for the higher quantity of light-ends in the partially refined shale oil, Rubel of Union Oil states that $3.70/bbl. would be a reasonable price for the shale-oil products. Thus $3.70 – $2.65 or $1.05/bbl. appears to Union Oil to be the margin upon which the shale investment rests at the present time.

Future Research and Development

MINING AND RETORTING

During the past ten years considerable research effort has been devoted by both government (*5*) and industry toward the technology involved in the processing of oil shale to produce liquid fuels. Commendable strides have been accomplished in mining, in improved design of the conventional vertical retort, and in refining techniques for the shale oil obtained by pyrolysis. By comparison, however, relatively little has been accomplished in advancing knowledge of (a) the nature of the organic matter itself, (b) its chemical constitution and relationship to the inorganic matter present, and (c) the mechanism of its decomposition under the action of heat. On this basis it is not surprising to find that little or no new or novel processing techniques have resulted from the last decade of research. Such technological advances can best be assured by the accumulation of sufficient new knowledge of the fundamental nature of oil shale to provide a basis for improved process design.

It would appear that, if the Bureau of Mines oil-shaft mining research is successful (see above) mining costs can be reduced so as to subtract approximately 1 cent/gal. from the present estimated cost of finished gasoline. It is unlikely that further savings of any magnitude beyond this can be effected in mining shale. It is possible that crushing costs can be reduced further. Since crushing costs are not a substantial proportion of total cost at present, this fact is important mainly in permitting smaller shale particles (better heat transfer) for processing.

It is obvious that the greatest savings must be sought in the retorting and initial refining steps. These two steps must be considered together since it is primarily the retorting process which determines the shale-oil characteristics to which further refining processes must be tailored.

Little hope is held for further substantial improvements in retorting, as conducted in vertical retorts. These retorts in their present form (Union Oil or Bureau's gas-combustion design) are thermally efficient and require little water. They produce about as rapid a heat-transfer rate as is possible to attain, consistent with yield and process economics (e.g., crushing costs vs. particle size).

REFINING

In order to effect additional economics in retorting and initial refining, it is desirable, if possible, to (a) increase throughput rate substantially, (b) produce a pipeline crude directly from the retort, and (c) reduce nitrogen (and perhaps sulfur) content of the resulting shale oil appreciably.

More fundamental data on the nature of oil shale is required before the above improvements can be attempted. Structure studies on the organic matter, in order to determine its chemical configuration, are still sorely lacking. The character of the *original* nitrogen, sulfur, and oxygen complexes are still not understood. The chemical and physical relationships of organic matter and inorganic matrix are still unknown.

Knowledge along the above lines might well lead to improvements of the type sought. For example, if the nitrogen complexes were to be primarily concentrated in one particular form of kerogen (perhaps a porphyrin complex), efforts could be directed toward chemical reactions designed specifically to destroy such complexes.

Another example is found in the problem of catalytic activity of the inorganic matter present. The surface areas estimated to date for spent shale argue against appreciable catalytic activity from this source, but these areas are not known with any accuracy. Cracking-catalyst activity would appear not to be of an acid type, but aromatization, cyclization, and the like might occur and be intensified. Whether specifically desirable catalytic activity can be enhanced (e.g., by pretreatment or the use of additives) is still a matter of speculation. A recent patent, however, makes claims along these lines, using mineral acids.

Many more examples of improvements could be cited. Suffice it to state, however, that only considerably more fundamental research can provide answers to these problems.

"Shale Petrochemicals"

Little attention has been given in this paper so far to the use of oil shale as a primary raw material for the chemical industry. From an economic point of view it would appear, in the light of present knowledge, that such chemical uses must be of primarily a by-product nature. In other words, any oil-shale chemical industry must be viewed in the same relationship to the parent fuel industry as is the petrochemical industry to petroleum refining. The importance of such a by-product industry cannot be ignored, however.

"Shale petrochemicals" selling in the range 5 cents to $1.00/lb., even if only 1 or 2% of a total shale industry's output can be a tremendous economic factor in reducing cost of the primary fuel products. This is obvious when it is considered that the fuels themselves sell only in the range of 1 to 2 cents/lb.

Murphy and Thorne (*2*) of the Bureau of Mines at Laramie have conducted research on high-temperature (1,000-1,650° F.) entrained solids retorting, which leads to large yields of aromatics (e.g., 3 gal. benzene and toluene/ton of 30 gal./ton shale at 1,450° F.) and light petroleum gases (80 lb. ethylene, propylene, and butadiene/ton). This process has naturally attracted the attention of the Dow Chemical Company, now a major owner of oil-shale property, and others.

Much additional research on chemical processing techniques is warranted (e.g., controlled halogenations, aminations, etc.). It is almost redundant to add that a clearer elucidation of the fundamental structure of oil-shale organic matter would aid considerably in directing such activity along profitable avenues. The so-called thermal solution of oil shale might be a worth-while processing technique in this regard. This process, to date, has been economically unsuccessful as a major retorting technique for fuels, in spite of higher heat-transfer rates and product yields, due to separation problems. Additional research along chemical lines might be warranted.

Literature Cited

1. Guthrie, B., and H. M. Thorne, "Encyclopedia of Chemical Technology," Vol. 12, p. 207, Interscience, New York (1954).
2. Murphy, W., and H. M. Thorne, Minutes of Industry—Bureau of Mines Oil Shale Conference, Laramie, Wyoming (August, 1954).
3. National Petroleum Council, "Synthetic Fuels Production Costs" (October 15, 1951).
4. Rubel, A. C., *Oil & Gas Compact Bull.*, **14**, No. 1, 24 (1955).
5. U. S. Bureau of Mines Annual reports, "Oil from Oil Shale" (1950 to 1955).

Presented at A.I.Ch.E. meeting, Glenwood Springs, Colorado.

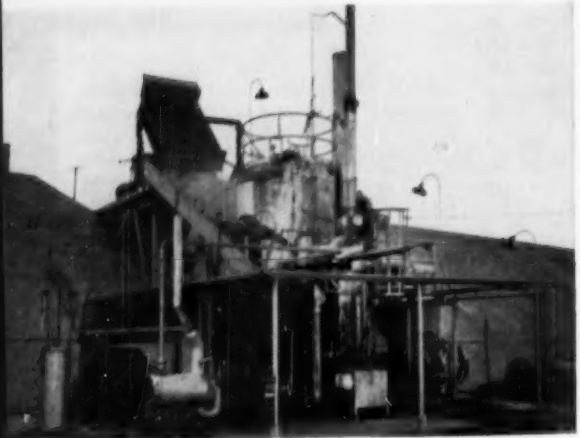


Fig. 1. Photograph of Union Oil Co. shale retort pilot installation.

ADVANCEMENTS IN FUEL PRODUCTION FROM OIL SHALE

Clyde Berg | Union Oil Company of California

The production of oil from shale antedates the production of oil from wells by about twenty years. When the latter production was developed, there were about fifty plants in the United States producing oil from shale and many similar plants in Europe, notably in Scotland and France. This industry was unable to compete with the oil from wells. Those few plants that survived prior to World War II were located in Scotland, Estonia and Manchuria.

The considerations regarding shale-oil production in the United States have been largely concerned with the shale deposit of the Picance Creek Basin of northwestern Colorado, which extends over an area of 1,000 square miles. It is probably the most concentrated fuel resource in the world. Potentially 350 billion barrels of oil are contained in this shale deposit, which averages approximately 500 ft. in thickness at an elevation of 5 to 8,000 ft.

Exploitation of this huge Colorado shale reserve depends upon the combined economic solution of mining, retorting, and refining of shale and shale oil. The Bureau of Mines has effected an important advance in the successful mining of shale in its demonstration mine near Rifle, Colorado (*1, 2, 3*). It has been estimated that a typical commercial shale mine can produce approximately 20,000 tons of shale/day.

In the United States considerable thought and effort have been given to the development of improved techniques for shale retorting and a variety of retorts has been proposed (*3*).

Development of Union Oil Retort

Development of the Union Oil retort was carried out in conjunction with economic studies on a variety of earlier shale-retorting methods. These studies emphasized the importance of economically handling the large quantities of heat which must be added and recovered from the shale in the course of retorting.

Many of the previously existing methods of shale retorting employed indirect methods of heat exchange to raise the temperature of the shale and condense the products of retorting. These designs led to high initial capital investments, frequently exceeding $3,000/bbl. of daily capacity. Associated with this high investment cost, most of the earlier shale-retorting processes incurred large utility requirements, necessitating huge quantities of cooling water, and frequently utilizing all the gas products from retorting, as well as some of the oil, in their operation.

Only the most economical means for effecting heat transfer to the raw, incoming shale and highly efficient heat recovery from the discharging clinker can result in low-shale-retorting costs.

Based on a paper presented at A.I.Ch.E. meeting, Glenwood Springs, Colorado.

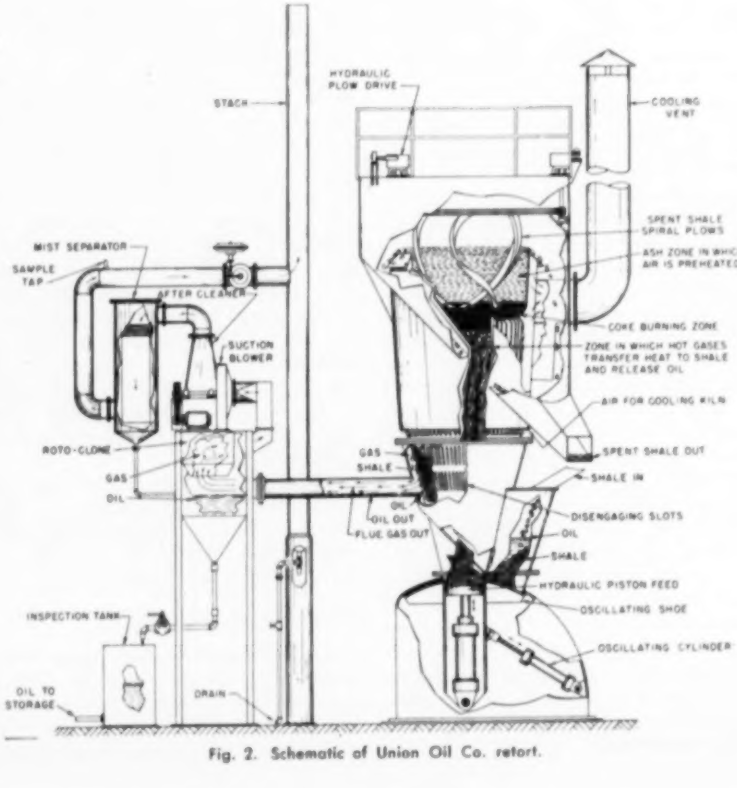


Fig. 2. Schematic of Union Oil Co. retort.

Table 1.—Retorting Plant Performance

Shale feed, tons/cd	20,000
Shale oil product, bbl./cd	13,125
Gas production (dry, total), M std.cu. ft./cd.	270,000
Shale ash, tons/cd	12,500
Air rate to kilns, M std.cu.ft.	203,000

cd—means calendar day.

Table 2.—Properties of Shale Oil

Gravity, ° A.P.I. at 60° F.	20.7
Sp. gr. at 60° F.	0.930
Distillation (50 mm. vac.), ° F.	
Initial	402
10	536
20	622
30	692
40	764
50	814
60	836
70	865
80	889
90	Cracked
Water, %	0.1
Ash, wt. %	0.03
Conradson carbon, %	4.57
Viscosity, S.S.U. at 100° F.	223
Viscosity, S.S.U. at 210° F.	46
Pour point, ° F.	90
Sulfur, wt. %	0.77
Nitrogen, wt. %	2.01

Table 3.—Composition of Gas Produced in Retorting of Shale

component	mole %
Air	2.0
Nitrogen	57.5
Argon	0.6
Carbon monoxide	4.7
Carbon dioxide	29.7
Hydrogen	2.2
Sulfide	0.1
Methane	1.0
Ethylene	0.6
Ethane	0.4
Propylene	0.5
Propane	0.2
Butylene	0.3
Butane	0.1
Pentenes	0.1
	100.0
Avg. mole wt.	32.44
Gross heating value	83.3 B.t.u./std.cu.ft.

Table 4.—Inspections of Shale Oil Coker Distillate

Gravity, °A.P.I.	32.6
Nitrogen, wt. %	1.47
Sulfur, wt. %	0.74
Engler distillation, ° F.	
Initial	172
10	337
30	440
50	524
70	582
90	654
Max.	713
Recovery, %	98.0

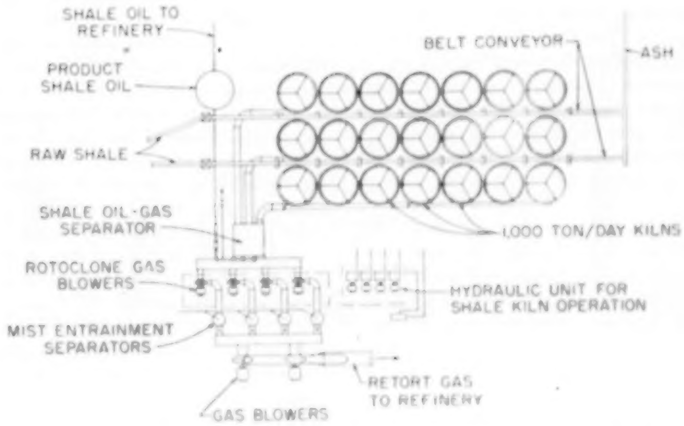


Fig. 4. Plan of 20,000 ton/day shale retorting plant showing arrangement of retorts.

Use of an external source of cooling to reduce the temperature of the ash and the products of retorting is undesirable because of the magnitude of the heat load, as well as the serious fouling problem which must be contended with in maintaining effective heat transfer surface.

The Union Oil retorting process employs direct heat exchange between high temperature flue gas employed for retorting and the shale being processed. Because of the large surface of shale available for heat transfer, effective heat exchange is realized and a high thermal efficiency is obtained for the over-all retorting operation. The products of retorting are condensed directly on the raw, incoming shale, thereby eliminating the need for cooling water and essentially all outside utilities.

The residual carbon remaining on the shale after retorting constitutes an important source of fuel, both for maintenance of the retorting operation and as a source of energy for outside use. The energy of this carbon is recovered in useful form by the producer gas operation occurring in the retorting kiln simultaneously with the recovery of shale oil. This producer gas, together with the normal hydrocarbon gases produced in retorting, provides a substantial auxiliary fuel source.

The Union Oil Company underfeed retorting method was publicly demonstrated in a 50 ton/day unit in 1950 (*4, 5, 6*).

This retorting unit employs countercurrent flow of shale and air in a kiln utilizing bottom feed of solids. The ash and clinkers, cooled by countercurrent heat exchange by the incoming shale, are removed overhead and the oil drained from the bottom of the unit. The oil is distilled by a downward flow of heat furnished by combustion of the residual carbon on the shale clinker near the top of the kiln. The heat available from combustion of the stack gases far exceeds the power of the plant. Almost perfect heat exchange is obtained in the units since the incoming air is preheated by the spent hot clinker and the products of distillation are condensed on the cool, incoming shale.

Commercial Shale Retort Detail

Details of the continuous Union Oil shale retort (photograph Figure 1 and diagram Figure 2), reveal that the unit employs a cylindrical kiln with a hydraulically operated underfeed mechanism.

Movement of the granular shale is upward through the unit with overflow at the top. Clinkers are removed by a hydraulically actuated plow mechanism and fall into an ash-disposal chute. The sections of the kiln expand gradually upward, minimizing restriction to movement. The shale kiln employs an externally finned retorting section with cowling to direct air flow over the fins and control shell temperature. A secondary stack draws the air through the cowling section. Cooling of the shale by this arrangement is designed to effect a maximum metal temperature of 750° F. at the burning zone. A conical-slotted section below the retorting section effects the separation of the oil and gas from the shale bed. A cooler surrounds this section and the gas is withdrawn from this by a rotoclone blower.

The feeding mechanism at the base of the unit is so constructed that any fines falling through the grate return to the feeding piston and are reintroduced into the unit. This prevents the gas and oil collecting housing from plugging due to accumulation of fines. The feeding mechanism is filled with oil to a level just below the slot edges, providing a liquid seal which

prevents the blower from pulling air in through the feed hopper.

Retort Operation

Operation of the shale kiln is entirely automatic. The flow of air is controlled by an automatic-flow-control system. A temperature controller actuated by thermocouples located at the shell of the retort maintains the burning section approximately 3 ft. below the top of the kiln by control of the feeding mechanism.

The retorting section may be divided into three zones: in the top zone heat exchange between incoming air and hot clinkers is effected; in the lower portion of this top zone combustion of the carbon residue on the clinker is effected and produces flue gas with a temperature near 2,000° F. This flue gas progresses into the second zone, termed the retorting zone, wherein the oil is educted from the shale. The mixture of shale oil vapors and flue gas progresses downward into the third zone, termed the condensation zone, where the incoming green shale is heated and the products of eduction are cooled and condensed. The temperature of the exit oil and gas from the kiln approaches within 20° of the shale being charged. A typical temperature profile of the shale kiln is graphically illustrated in Figure 3.

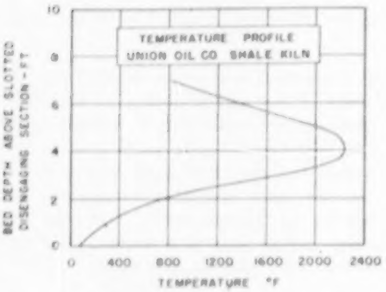


Fig. 3. Typical temperature profile in fifty ton/day shale unit.

It has been estimated that a typical commercial mine can produce approximately 20,000 tons of shale/day. The retorting plant designed to handle this production of shale will employ a battery of retorts, each having a capacity of 1,000 tons of shale/day. In Figure 4 is given the plot plant of a commercial retorting unit of this capacity. It will be noted that the gas-handling system of this unit will be centralized, as well as that of the hydraulic power-supply equipment.

Retorting Plant Performance

Table 1 shows yield data for a typical operation of a shale-retorting plant processing 20,000 tons of shale/day and averaging 30 gal./ton. The shale oil produced from the Union type underfeed retort is characterized by relatively constant quality with little variation due to fluctuations in operating conditions. Typical properties of the shale oil are given in Table 2. Of particular interest are the exceptionally low water and ash contents of this crude shale oil, averaging 0.1 wt. % for the former and 0.03 wt. % for the latter. Gas produced in retorting of Colorado shale amounts to 13,490 std.cu.ft./ton and has the composition given in Table 3. The ash produced amounts to 62.8 wt. % of the fresh shale. Heat efficiency of the retorting operation is very high and the total energy requirements for operation of the retort amount to only 7% of the gas yield and less than 2% of the energy value of the total retort production.

Coking of Shale Oil

As the first step in the refining of shale oil, it is necessary to adjust the boiling range to that consistent with fuels in volume demand. An over-all yield of 79.6 vol. % 700° F. end-point distillate can be obtained in the coking of crude shale oil. Table 4 gives the boiling range and inspections of the coker distillate. In a comparison of the characteristics of the crude shale oil given in Table 2 and those of the coker distillate, it will be noted that although a substantial change in reduction in boiling range is effected, only minor reductions occur in the nitrogen and sulfur content.

In the course of coking of shale oil, substantial quantities of methane and ethane are produced which are utilized for the production of hydrogen by reforming with steam. This hydrogen is consumed in the subsequent refining steps. In Figure 5 a flow sheet is given of the coking operation and hydrogen production carried out as the initial step in the refining of shale oil. It will be noted that the coker distillate is fractionated into light and heavy distillate, the light distillate being in the gasoline range and the heavy distillate being in the diesel range.

Table 5.—Coking and Hydrogenation of 100,000 bbl. Crude Shale Oil

Shale retorted, tons	152,300
Retort gas, M std.cu.ft.	2,056,000
Ash, tons	95,100
Refinery gas, M std.cu.ft./(1,060 net B.t.u./std.cu.ft.)	51,000
Jet fuel, bbl.	*51,500
Diesel fuel, bbl.	*33,500
Coke, tons	2,360
Ammonia, tons	124
Sulfur, tons	86
Total liquid ref. prod., bbl.	*85,000

Table 6.—Refining 100,000 bbl. Crude Shale Oil with Coking, Hydrogenation, Reforming, and Catalytic Cracking

Shale retorted, tons	152,300
Retort gas, M std.cu.ft.	2,056,000
Ash, tons	95,100
Refinery gas, M std.cu.ft./(1,060 net B.t.u./std.cu.ft.)	50,100
Gasoline, bbl.	*50,700
Diesel, bbl.	*26,050
LPG, bbl.	*3,570
Fuel oil	*1,200
Coke, tons	2,360
Ammonia, tons	184
Sulfur, tons	86
Total liquid ref. prod., bbl.	*81,520

Upgrading of Heavy Coker Distillate

The upgrading of coker distillates of shale oil requires removal of organically combined sulfur, nitrogen, and oxygen, as well as the saturation of highly olefinic and reactive hydrocarbons.

This can be effected by catalytic refining by the cobalt-molybdate process (7, 8) or the recently announced Union Oil Company process, Unifining (9). In this operation the above contaminants are converted into hydrogen sulfide, ammonia, and water. Hydrogenation of the olefins in the stock occurs, but under the conditions normally used, essentially none of the aromatics present are hydrogenated. Conversion of the sulfur, nitrogen, and oxygen compounds to saturated hydrocarbons and inorganic byproducts occurs by the cleavage of carbon-sulfur, carbon-nitrogen, and carbon-oxygen bonds. Essentially no carbon-to-carbon bonds are broken.

Unifining Process

Figure 6 represents the flow sheet of a Unifining plant treating shale oil heavy coker distillate. It will be noted that before entering the catalyst-containing reactor of this refining plant, the heavy coker distillate and recycle hydrogen are preheated by heat exchange in separate exchangers against the hot reaction products. The exothermic heat of reaction obtained in the treatment of coker distillates is of sufficient magnitude to make the process independent of appreciable furnace preheat requirements, except during startup periods. Hydrogen sulfide and ammonia in the recycle gas are removed by absorption at reaction pressure. Regeneration is accomplished by adding air to an inert stream of combustion gas which is circulated over the catalyst by means of a blower. Inert gas for this purpose is generated by burning fuel gas in a special furnace. The product of refining in this operation meets the specifications of premium diesel and jet fuel.

Refining of Shale Oil

The refining steps and techniques now known (*8, 10*) for the upgrading of shale oil can lead to premium diesel fuel, jet fuel, and motor fuel. By carrying out the coking of crude shale oil, followed by refining of the full range coker distillate, approximately 85% over-all liquid yield of premium high cetane diesel fuel and jet fuel is obtained. The sequence of these operations is presented in the flow sheets given in Figures 5 and 6 (see also Table 5). The stocks derived by the above sequence of refining steps are directly useful as military fuels. For civilian use, however, it is desirable that a high octane motor gasoline be produced rather than jet fuel, and it is not essential to produce high cetane diesel fuel. To meet domestic requirements, it is preferable to carry out coking of the crude shale oil, as illustrated in Figure 5, followed by Unifining of the heavy coker distillate, similar to Figure 6, together with cobalt-molybdate reforming of the light coker distillate, as illustrated in Figure 7, followed by catalytic cracking of the hydrogenated heavy coker distillate and blending of gasoline stocks in existing refineries near the population centers. Table 6 gives the products derived from refining 100,000 bbl. crude shale oil by this method. It will be noted that an over-all yield of 81.5% in liquid products is obtained by this refining sequence and that the gasoline middle boiling ratio is 1.95, corresponding to the national average. Inspections of the products are equal or better than those of conventional petroleum products currently marketed.

Application of the Hyperforming Process

A distinct advance in the refining of inferior grade stocks was made when the Union Oil Company announced the Hyperforming process (*10, 11*). This is a reforming and refining process which utilizes a moving bed of cobalt-molybdate catalyst and which is suitable for the refining of high nitrogen, high sulfur gasoline stocks from shale oil, Santa Maria crude, and other inferior stocks.

The Hyperforming process permits the refining of blends of straight-run gasoline and substantial quantities of high nitrogen, high sulfur distillates from shale oil and high-sulfur crudes. The efficient exchange of hydrogen between the straight-run gasoline and the inferior stock permits refining without the requirement of outside hydrogen. In the Hyperforming operation the hydrogen liberated in dehydrogenation of naphthenes to aromatics is reutilized within the reactor to eliminate quantities of nitrogen, sulfur, and oxygen in the inferior stock. Olefins are

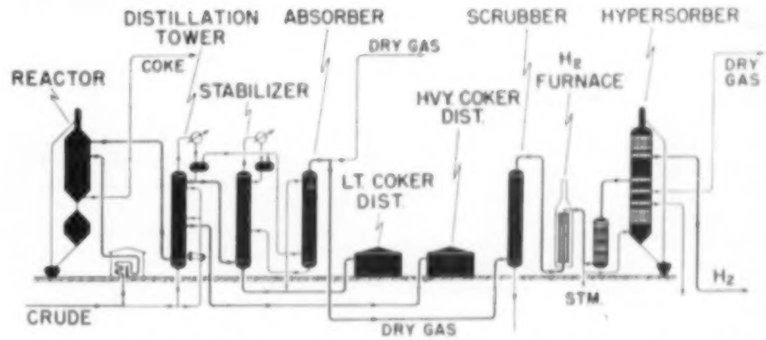


Fig. 5. Flow sheet of coking operation and hydrogen production in refining of shale oil.

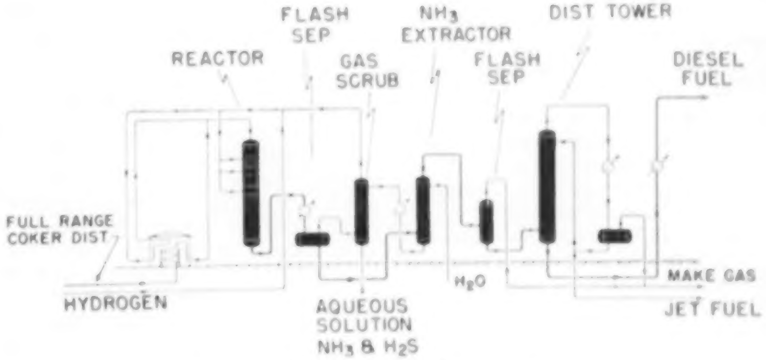


Fig. 6. Flow sheet of Unifining plant for shale oil.

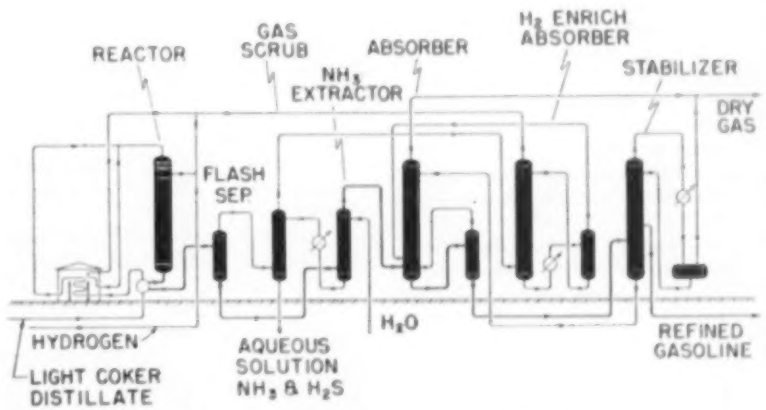


Fig. 7. Flow sheet of Unifining plant for shale oil.

saturated as well. The features of this process open the possibility of refining incremental quantities of shale oil in a refinery where straight-run gasoline stocks are available without the generation of outside hydrogen.

Economics

During 1951 a petroleum industry survey was made of the production of shale under the auspices of the National Petroleum Council. This study constituted the most extensive and thorough evaluation of shale oil made to date *(12)*. It included a study of the hydrogenation of coal as a possible source of synthetic fuel. The work was subdivided among forty-seven men of industry who were experts on synthetic fuel processes. More than 190 meetings were held at an estimated cost to industry of $300,000. The results of this Petroleum Council study have been published *(13)*, but are not reproduced here in the interests of brevity. They show that the production of oil from shale is our most attractive source of synthetic fuel and warrants continued attention by the petroleum industry.

Literature Cited

1. Ertl, Tell, *Am. Soc. Mech. Engrs. Conference*, Amarillo, Texas (Oct. 3-6, 1948).
2. Gardner, E. D., and E. M. Sipprelle, *Mech. Eng.*, **72**, No. 9, 701 (September, 1950).
3. Hull, W. Q., Boyd Guthrie, and E. M. Sipprelle, *Ind. Eng. Chem.*, **43**, No. 1, page 2 (January, 1951).
4. Berg, Clyde, *Petroleum Refiner*, **27**, 9.2, page 76 (September, 1948).
5. Reed, Homer, and Clyde Berg, *Mech. Eng.*, **71**, No. 8, 639 (August, 1949).
6. Berg, Clyde. Second Oil Shale and Cannel Coal Conference, Glasgow, Scotland (July 4, 1950).
7. Berg, Clyde, W. E. Bradley, R. I. Stirton, R. G. Fairfield, C. B. Leffert, and J. H. Ballard, *Trans. Am. Inst. Chem. Engrs.*, **43**, No. 1, page 1 (January, 1947).
8. Reed, Homer, Clyde Berg, and Hugh Multer, Colorado Mining Association, Denver, Colorado (January 31, 1949).
9. Grote, H. W., C. H. Watkins, H. F. Poll, and G. W. Hendricks, WPRA meeting, San Antonio, Texas (March 30, 1954).
10. Berg, Clyde, Athabasca Oil Sands Conference, Edmonton, Alberta, Canada (September 12, 1951).
11. Berg, Clyde, *Am. Inst. Chem. Engrs.* meeting, San Francisco, California, (September 15, 1953).
12. Announcement by W. S. S. Rodgers, chairman, National Petroleum Council Committee on Synthetic Liquid Fuels Production Costs, Washington, D. C. (October 31, 1951).
13. Subcommittee report to National Petroleum Council Committee, "Synthetic Fuels Production Costs," (October 15, 1951).

INTEGRATION

The pace of important company mergers and acquisitions has been accelerating since 1949. According to the Federal Trade Commission's "Report on Corporate Mergers and Acquisitions," the number in 1954 was three times that of 1949 and just slightly less than that for 1946 and 1947—the post-war merger peak.

Merger activity by firms in the chemical group was the third greatest of any industrial group, exceeded only by the nonelectrical machinery and the food and kindred products industries. From 1948-1954, in the chemical industry, seventy-three firms acquired 168 others. The most active acquiring firms in the chemical field included Olin-Mathieson, Borden, Food Machinery & Chemical, American Marietta, Allied Chemical, National Lead, General Tire & Rubber, and International Minerals & Chemical.

Thus a merger trend, and one pointing in a good many cases toward integration, can be seen. I think that it would be generally agreed that the trend in the chemical industry has been toward integration for some time. The urge is to diversify and expand and, in the process, to strengthen the company's competitive position. This is sound so long as it does not place the diversifying company in destructive competition with its own customers. In these instances where integration is desirable it should not be regarded as a short-term expedient, capable of solving, say within a year, long-existent problems or of bolstering a weak financial picture. Rather should it be considered a long-range objective with carefully formulated plans looking toward new products, new processes, better distribution. Such plans must consider, in a broad sense, specific goals for diversification and integration. At the same time the company's special qualities must also be evaluated in order to capitalize on them.

When these evaluations have been made, the search for the new company or product can begin. This can be carried out, for example, by the market research and development group following the pattern defined by top management. However, since the final decision and action rest with company heads, they should be prepared to weigh certain factors besides purely economic ones. There is the need to avoid moves which might be counter to antitrust legislation and to consider the personal or human side of integration. Thought must be given to the problem of principal executives in the new, enlarged company to personality clashes, to pension funds, and to the different objectives of the merged companies. Not all these problems are easily resolved, and some may require not only a high order of diplomacy and tact but also months of time.

As chemical companies integrate vertically towards raw material sources, move closer to ultimate consumers, or expand horizontally into other facets of the industrial picture, the sales base widens and the need for new plant becomes greater. Capital expenditures for the chemical and allied products field in 1955 are estimated at $1.2 billion, or just under 1954 expenditures.

Because the supplying of money, or arranging to secure it from a diversity of sources, is a business also desirous of expanding, banks, investment companies, individuals, and others are increasingly involved in the steps leading to industrial company mergers or acquisitions. Whereas this financial activity is not new, it has been accelerated to keep in step with the desires of clients or prospective clients. Obviously many recent mergers have been greatly facilitated thereby, and the large supplemental expenditures required have been arranged for expeditiously.

Suppose we consider in some detail several of the reasons for integration. The examples selected are by no means all-inclusive and the objectives in each instance leading to integration may not be exactly as I have interpreted them. Obviously, only the company officials and their close business associates would have the complete story in each instance.

Reasons Behind the Desire to Integrate

1. To improve raw material position, — e.g., production of elemental phosphorus by a manufacturer of phosphates so that a continuing supply of phosphoric acid will be available for conversion to end-chemicals.

2. To strengthen competitive position by utilizing more than one process to produce basic raw materials or intermediates, — e.g., ethylene glycol production by both the chlor-

IN THE CHEMICAL INDUSTRY

Richard B. Schneider | Empire Trust Company, New York

hydrin and oxidation processes using ethylene as the starting point; e.g., acetylene production from calcium carbide and by controlled oxidation of natural gas.

3. To improve competitive position through better distribution. This can result from:

(a) upgrading basic products to enable capturing a new class of market — e.g., an acetylene manufacturer recently elected to purchase a company making vinyl acetate—the acetylene raw material can thus be upgraded one step and the new owner can participate in the plastics industry as a basic supplier.

(b) acquiring a substantial user of a commercially important product or group of products — e.g., the purchase recently of a producer of wet process phosphoric acid and derived phosphates by a major manufacturer whose product line included sulfuric acid, soda ash, and caustic soda. This acquisition afforded both integration and diversification.

(c) acquiring a marketing unit whose needs then can be supplied completely or partially by the buyer's manufacturing facilities — e.g., recent purchase of an ammonia distributor by an oil company subsidiary preparing to erect and operate an anhydrous ammonia plant.

4. To take advantage of raw materials available to one company and of technology and marketing experience available to a second through forming a jointly owned subsidiary.

5. To make a better profit on available starting material which could be a source of chemicals — e.g., decision by a natural gas producer to make ammonia and related products rather than restrict himself to selling the natural gas for pipeline transmission; e.g., consideration by two natural gas producing companies of constructing and operating a plant to produce ethylene which in turn would have been marketed to chemical manufacturers.

6. To utilize by-products or otherwise waste materials — e.g., companies not usually classified as part of the chemical industry have undertaken chemical activities. Steel companies produce ammonium sulfate and coal tar crudes such as benzol, toluol, xylol. Some of the steel companies make intermediates of their crudes. Meat packers have become the source of special types of pharmaceuticals.

Occasionally integration is achieved in a company by reversing its traditional pattern of expansion or diversification. An example can be noted in the National Distillers' plan to become an increasingly important basic unit in the chemical industry by which it has divested itself not only of some of its liquor subsidiaries but also of less closely related segments of U. S. Industrial Chemicals as well. Concentration thus is being achieved on products from hydrocarbons, including ammonia and related chemicals, polyethylene and the like.

Although much can be written on the advantages of integration, there are occasions when it may be disadvantageous. Generally, companies strive to avoid competing directly with their customers, thus soda ash producers so far have not gone into the glass business. Conversely, though, Pittsburgh Plate Glass Company has integrated its activities by producing a substantial portion of its own ash requirements through Columbia-Southern Chemical Corporation. In casting about for a measure with which to gauge the extent of an industrial company's entry into fields dominated by its customers, I am led to think that *size*, hence all-around strength, is more than ever the guidepost for a company's actions.

The larger the company the more it can afford to gamble on the outcome of competition with customers, its own goal being the higher profit margins attainable on upgraded products sold to the ultimate consumer and the greater control which can be exercised over the use of the component parts. Small- and moderate-sized companies would be ill-advised to take the risk unless a unique combination of circumstances exists which would provide, for example, strong patent protection and an assured market position for sufficient time to enable satisfactory payout of the required investment.

Integration can however, be carried to extremes with the result that excessive amounts of capital are invested in facilities to produce chemicals which might more advantageously be purchased. Volume products are frequently involved. One might consider vinyl chloride monomer since a number of the users of polyvinyl chloride have decided to construct plants to make their own polymer. Conceivably, they could make the monomer, too, but that would then mean having as starting materials either ethylene or acetylene and hydrogen chloride. Since chlorine producers have equipment already in operation and since some either have ethylene or acetylene or could secure these hydrocarbons readily, their costs for monomer in quantity should be lower than those attainable by a newcomer, even though he were to buy his chlorine rather than install a plant to make it. Some engineering companies are submitting estimates on vinyl chloride monomer plants with modest capacity for installation by small resins manufacturers or fabricators, but it seems that for a relatively small present or prospective producer of polymer to feel that he should also become a producer of monomer is carrying integration a step too far. It gets inexperienced companies into the chemical business at a point where they may well have difficulty competing.

With emphasis on integration, and with large companies constantly seeking to improve their competitive position through acquisition, there is a strong and continuing opportunity for the establishment and growth of specialty companies. The attraction, other than independence of operation, is capital gain which the organizers can take by selling out after a few years to a larger unit in the chemical or related process industries. Ingenuity and aggressiveness can command an even greater ultimate reward under present business conditions than when less thought and effort are given to diversification and expansion. There are adequate funds seeking advantageous investment frequently with a preference for long-term gain rather than immediate income. Thus, individuals with the necessary background and experience and with well-thought-out projects need not lack for careful hearings in the financial community. This is a healthy situation because the chemical industry thrives on change and new developments and there must be a steady flow of new ideas and projects.

Integration in the chemical industry is both a challenging topic for discussion and certainly a statement of fact. Security analysts continue to agree that the qualities inherent in a good chemical company make for a more rapid growth pattern than can be found elsewhere. Integration, diversification, and expansion are terms which have much in common. Collectively, and when judiciously planned, they can represent a highly acceptable and useful type of industrial as well as individual company progress.

Presented at A.I.Ch.E. Lake Placid meeting.

liquid-film efficiencies on sieve trays

Alan S. Foss and J. A. Gerster | University of Delaware, Newark, Delaware

Use of sieve or perforated plates in large-scale absorption and distillation columns has gained wide acceptance in recent years. Some of their obvious advantages over bubble-cap trays hardly need experimental confirmation. One of their strongest attractions as shown by Jones and Pyle is their low initial cost (*10*). Moreover, it is expected that hydraulic gradients on sieve trays are small. Since caps on bubble-cap trays offer resistance to the flow of liquid across the tray, large hydraulic gradients are often encountered. On sieve trays, however, the only resistance offered to liquid flow is that of the rising gas bubbles. This condition requires only small hydraulic gradients, even at high liquid rates. Of particular interest is that plate efficiencies of sieve trays are reported to be high. No comprehensive studies of their mass transfer characteristics have been published, however, although recent papers (*1*) and (*12*) report stability and pressure drop behavior.

Earlier work with bubble-cap trays has suggested that sieve trays could be used profitably in extractive distillation. A common characteristic of extractive systems is that most of the resistance to mass transfer lies in the liquid phase. For such a case, high liquid retention time on the plate is desirable for optimum efficiency. Further, favorable vapor-liquid equilibrium requirements demand large solvent concentrations in the liquid phase, which results in high liquid loading for these columns. This requires a tray design which gives a low hydraulic gradient. Work by Remer, Field, and others (*15, 3, 5, 6, 7*) showed that tunnel caps with cap faces spaced 4 in. apart gave the lowest hydraulic gradient and lowest linear liquid velocity of any bubble-cap design; and in spite of the wide cap spacing, efficiencies were also the greatest. Sieve trays, however, allow an even lower hydraulic gradient and a lower linear liquid velocity. Because the liquid is aerated completely at every point on the tray, sieve-tray performance should be superior to that obtained with a tunnel cap tray.

Because the resistance to mass transfer in extractive systems lies predominantly in the liquid phase, a system having only liquid-phase resistance was chosen for study. It was recognized that the results obtained with such a system would be useful in the prediction of liquid-phase efficiencies of any other system. Also it was presupposed that the greatest difference between action on bubble-cap and sieve trays would occur in the liquid phase. The absence of bubble caps would presumably permit a greater degree of liquid mixing on the sieve tray, whereas it was thought that the path of the vapor passing through the liquid wolud be the same on both bubble-cap and sieve trays.

The system oxygen-water-air was selected to measure liquid-film efficiencies. Oxygen was stripped from oxygen-rich water flowing across perforated plates by atmospheric air passing up through the plates. The solubility of oxygen in water is very small, making the ratio of the slopes of the equilibrium and operating lines large. When this is the case, the resistance to mass transfer in the gas phase is negligible compared to the resistance in the liquid phase. In addition, the fairly simple analytical procedure for accurate determination of dissolved oxygen in water was also a factor in the selection of this system.

Experimental Equipment

The perforated plates used were 1/16 in. thick having holes 3/16 in. in diam. spaced to give total hole areas of approximately 4, 8, and 11% of the total tray area. It was felt that the 3/16-in. hole size was intermediate in the range of hole diameters in industrial use. Use of trays with less than 4% free area would not permit gas throughputs comparable to those used in this study without excessive gas pressure drop. Trays having free areas above 11% were difficult to maintain in stable operation in that entrainment of water in the air and passage of water through the perforations often became excessive.

In all but a few cases, the length of liquid travel on the plates was limited to 18 in. Tray lengths longer than 18 in. provided exceedingly long liquid contact times so that liquid efficiencies above 90% were sometimes obtained. It was desired that the efficiencies remain below this value since it was difficult to determine accurately values of efficiency above 90%. Tray lengths less than 18 in. were not used, for it was thought that any nonuniform conditions at the liquid inlet and outlet of the tray would constitute too large a portion of the active tray. The selection of an 18-in. tray length was the best compromise that could be made among these factors.

Liquid-film efficiencies were measured with variations of liquid rate, gas rate, and outlet weir height. The operating range in which water passed down through the perforations was not investigated. This condition prevails at high outlet weir heights, high liquid rates, and low gas rates. No studies were made in the range of operation where entrainment became excessive. Very high gas rates at low weir heights brought about this condition. The stable range of tray operation is said to lie between these two limits. Efficiencies were measured within this range of stable operation by varying the gas velocity through the perforations between 45 and 79 ft./sec., with the use of liquid rates between 30 and 70 gal./(min.)/(ft. of weir length) at 1-, 2-, and 4-in. outlet weir heights. The choice of liquid rates depended primarily on the choice of tray length and somewhat on tray stability. Actually, it was necessary again to compromise in the selection of both liquid rates and tray length. It was necessary to limit the time of contact of the liquid with the gas so that the efficiencies of 100 per cent would not be attained. Yet a tray length as long as possible was desirable in order to minimize the effect of any nonuniform conditions at the ends of the tray. Use of liquid rates between 30 and 70 gal./(min.)/(foot of weir length) on a tray 18 in. long was satisfactory from the standpoint of contact time and end effects as well as tray stability.

Literature reporting sieve-tray performance is sparse. Recently Mayfield *et al.* (*12*) and Arnold, Plank, and Schoenborn (*1*) made valuable investigations of gas pressure drop character-

Details of experimental apparatus are on file (Document 4766) with A.D.I. Auxiliary Publications Project, Library of Congress, Washington, D. C. Table 2 is also on file. Photoprints are obtainable by remitting $1.25 or $1.25 for microfilm. These data are also available from the authors.

istics and stability limits of sieve trays. West, Gilbert, and Schmizu (*19*) used perforated plates in a small diameter column in an attempt to determine the interfacial area available for mass transfer within the froth. Few efficiencies were reported. Nandi and Karim (*13*) investigated the effects of hole size and total hole area on efficiency in a 2¼-in. diam. column but did not separate the operating variables sufficiently so that firm conclusions could be drawn. Studies of the entrainment characteristics of sieve trays as well as a general treatment of the effect of liquid concentration gradients on efficiency has been reported by Kamei and Takamatsu(*11*). Stone (*17*) has recently reported efficiencies of a sieve tray with 5 ft. of liquid travel. The investigation was confined mostly to the stripping of oxygen and carbon dioxide from water with air. Several other systems were also used but the range of operating variables investigated was quite limited.

Gerster *et al.* (*5, 7*) have demonstrated the applicability of the addition of the separate liquid and gas phase resistances to mass transfer in the prediction of plate efficiencies. Separation of the total resistance into those of the liquid film and gas film greatly facilitates the investigation and analysis of the mechanism of mass transfer on operating trays. This separation of resist. .s is a necessity as well as a convenience since changes in the primary operating variables affect the gas-film efficiency in an entirely different manner from the way they affect the liquid-film efficiency. The efficiency results shown here may be converted to liquid-film efficiencies for the particular system in question by using the ratio of the Schmidt groups for the two systems as described by Gerster (*5*).

The liquid-film plate efficiency, E_L, is defined as

$$E_L = \frac{x_1 - x_2}{x_1 - x^*} \qquad (1)$$

For the particular case of no mixing of the liquid in the direction of liquid flow, this quantity may be related to the number of liquid-film transfer units N_L. This relationship is obtained by solving the following equation resulting from a material balance of a differential element of aerated liquid dZ,

$$-Z_H L dx = k_L a Z_F (x - x^*) dZ \qquad (2)$$

where Z_H is the total length of liquid travel in the active portion of the tray and Z_F is the height of the aerated liquid above the tray floor. Integration over the entire tray length gives

$$N_L = \ln (1 - E_L) = \frac{k_L a Z_F}{L}. \qquad (3)$$

It is realized that the above relationship between N_L and E_L is not strictly correct for an actual operating tray because the liquid is mixed to some unknown extent. At the present time, no satisfactory method has been developed to account for the effect of partial liquid mixing on the calculated value of N_L. The true value of N_L lies somewhere between that calculated assuming no liquid mixing and that assuming complete mixing. Calculation of N_L assuming no liquid mixing was chosen because it was felt that this condition would be closely approached in the range of tray operation investigated.

Since N_L is a more fundamental quantity than E_L, correlation of results of previous investigations have been of N_L rather than of E_L. Gerster *et al.* (*6, 7*) have shown that N_L is directly proportional to the time of contact of the liquid with the gas and proportional to the interfacial area available for mass transfer within the foam. Results of the present work are correlated and explained by similar methods.

Apparatus

Experimental tests were limited to hydraulic and mass transfer measurements for desorption of oxygen from oxygen-rich water by air at atmospheric pressure. The single-plate unit consisted of two constant-width flow channels 9.5 in. wide and 45 in. long into which various sieve or perforated plates could be inserted. This unit was originally set up as a section of a large split-flow tray, and details of construction have already been described in the literature (*7*). In the present work the two sides of the tray were operated independently of each other.

The perforated plates used were fabricated outside this laboratory by punching holes in brass sheets 1/16 in. thick. The holes were noted to be uniformly round, free of burrs, and sharp on one edge only, the other edge having been indented by punching. An equilateral triangular hole spacing was chosen. Table 1 summarizes the important dimensions. All plates were installed level with their punched side up. When the entire 45-in. length of the tray was not used, the perforations not needed were covered with adhesive tape. In such cases the active section of the tray was confined to the portion immediately preceding the outlet weir.

Experimental Procedure

Prior to each day's operation the entire experimental unit including the bubble separating devices was flushed with water. This precaution removed any rust particles which might interfere with the analytical procedures. The flushing water was discarded and operation began with the use of fresh tap water. Air, water, and oxygen flow rates were set at the desired values. Preliminary investigations determined a rate of oxygen addition to the water which would not give an extreme excess of undissolved oxygen and yet would produce a fairly high dissolved oxygen concentration level of 15 to 16 p.p.m. Higher concentrations of oxygen could not be obtained without resorting to elaborate means of dissolving the oxygen. During operation the oxygen concentration in the holding tank remained close to the equilibrium value of about 8 p.p.m. Preliminary investigations also showed that 40 min. of operation at constant flow rates was more than necessary for the system to reach steady-state conditions.

All bubble separators were allowed to flush continuously at a rate of about 300 ml./min. Liquid samples from both inlet and outlet weirs were withdrawn into the bottom of 300 ml. glass-stoppered B.O.D. bottles immersed in an ice bath. The sampling rate, approximately 75 ml./min., was slow enough to prevent the transport of minute oxygen bubbles into the sample bottles. Samples of liquid were occasionally withdrawn in a similar manner from the floor of the operating tray at various points along the center line. No bubble separator could be used for this, however, and the sampling rate could not exceed 30 ml./min. In all cases sampling was not discontinued until the volume of the sampling bottle had been replaced at least five times by allowing the liquid to overflow the bottle. In stoppering the sample bottles, excess sample was forced out past the stopper, thus assuring no entrapment of air. All samples were analyzed immediately for dissolved oxygen by the Winkler method (*16*). The reliability of this method of analysis was confirmed by determination of equilibrium values of dissolved oxygen in the recirculated water. The experimental values checked literature values (*9*) consistently to within an average of 0.7%.

During the sampling period readings were recorded of the air and water orifice manometers, water temperature entering and leaving the tray, air temperature in the duct, gas pressure drop, clear liquid height manometers, and height of the aerated liquid. Estimation of the

Table 1.—Dimensions of Perforated Plates

Tray Number	Hole Diameter, in.	Hole Spacing, Center-to-center, in.	Per cent Free Area of Tray
1	3/16	7/8	4.16
4	3/16	5/8	8.0
2	3/16	17/32	10.6

Holes were punched on a triangular spacing in brass sheets 1/16 in. thick.

true height of the aerated liquid or foam above the tray floor was difficult since this height varied with time and position along the tray. The words foam and froth are used interchangeably in the context and both are meant to refer to the total mass of aerated liquid between the tray floor and the point where the gas finally escapes from the liquid on the tray. The best that could be done was to take time-averaged measurements at several points on the tray. One's hand was actually placed on top of the foam and its height estimated with a graduated scale. The error in foam height measurements is estimated at ±½ in. The general character of the foam and tray stability was also noted. The barometer reading was recorded once during operation. Maintaining the flows constant, a second series of measurements and samples of inlet and outlet liquid streams was repeated thirty minutes after the previous sampling was terminated. Only one set of samples of liquid along the tray length was taken per run, however.

Tray Stability

Before an experimental program could be begun, it was necessary to determine by preliminary investigations the range of operating variables which permitted stable tray operation. It was not the purpose of these preliminary studies to carry out an extensive investigation of tray stability, but merely to provide information for the design of the experimental program so that several trays could be compared under conditions of stable operation. Gas rate was found to be the most important factor affecting stability. For the trays used in the efficiency studies, an air velocity through the perforations of 35 to 45 ft./sec. was the approximate minimum that was necessary to keep the liquid from passing through the perforations. This minimum gas rate, of course, increased as outlet weir height and liquid rate were increased. The effect of weir height and liquid rate on tray stability will be discussed presently. In order to assure stable operation during the efficiency studies, gas velocities through the holes were maintained above 45 ft./sec. However, even at gas velocities above 45 ft./sec., some liquid passed through some of the perforations, but only spasmodically. These occasional drips were presumably due to some momentary local instability and occurred only on the trays having 8 and 11% free areas. High air rates through the perforations of the 11% free area tray of about 75 ft./sec. produced liquid entrainment which was qualitatively noted to be quite high. At hole velocities up to 100 ft./sec. through the 4% free area tray there was very little carry-over of liquid. In addition, gas velocities above the range 65-70 ft./sec. produced at low liquid hold-up a sloshing of the liquid in a direction perpendicular to the direction of liquid flow on all trays but the 4% free area tray. Thus, in order to avoid this unstable condition and also to avoid large amounts of entrainment, gas velocities were kept below 65 ft./sec. on the 8 and 11% free area trays during efficiency studies. Actual entrainment quantities were not measured in this study, but quantitative studies of the amount of entrainment on sieve trays and its effect on tray efficiency have recently been reported by Jones and Pyle (*10*) and by Kamei and Takamatsu (*11*).

High air rates were required to maintain the liquid on trays having free areas of 16 and 30%. The gas rates required for the 30% free area tray were so high that entrainment of liquid in the air above the plate became extreme before "raining" of liquid through the perforations had ceased. The 16% free area tray behaved similarly, but to a milder degree. It was thought that trays of this type which were difficult to maintain in stable operation would be of little practical interest where cross flow of liquid is used. High-free-area trays might be used, however, for counterflow operation, but because investigation of this type of operation was outside the scope of the present work, studies were limited to trays which exhibited stable operation within a commercially feasible range of gas and liquid rates.

The outlet weir height rather than the liquid rate was found to be the next important factor affecting tray stability. Actually, stability is dependent on the amount of liquid held on the tray, which in turn, is dependent on both liquid rate and weir height. A 4-in. outlet weir height was found to be the highest that would allow stable operation under reasonable variation of gas rate. A liquid rate of 80 gal./(min.)(ft. of weir) at a 4-in. outlet weir was the approximate maximum that could be tolerated on the 11% free area tray, whereas up to 110 gal./(min.)(ft.) at a 4-in. outlet weir on the 4% free area tray gave stable operation. The stability characteristics of the 8% free area tray lay intermediate between those of the 4 and 11% free area trays.

Foam and Hydraulic Characteristics

OBSERVED NATURE OF FOAM

In order to aid in the interpretation of the efficiency results, measurements and observations were made of certain properties of the aerated mass of liquid or so-called foam on the trays. It is to be remembered that the foam is referred to as the total mass of aerated liquid on the operating tray. The appearance of this foam was a characteristic that differed most noticeably among the conditions on the 4, 8, and 11% free area trays. The 4% free area tray produced a foam which had a uniform and homogeneous appearance at all gas rates. While several small bubbles constituted most of the foaming mass, several large jets of gas appeared to issue directly from the perforations and pass through the foam without dispersing. These jets or agglomerations of many bubbles were scattered randomly over the tray and did not persist at any one location. The 8 and 11% free area trays behaved in a manner similar to this at low gas rates, but at the high gas rates an extremely coarse spraylike froth was produced. Here the jetting of the gas through the foam was much more frequent, and it appeared that the gas was tending to replace the liquid as the continuous phase.

FOAM HEIGHT AND CLEAR LIQUID HEIGHT

The height of the aerated mass of liquid above the tray floor is believed to be one of the fundamental variables in mass transfer considerations. This height, Z_f, was measured by eye at several points on the tray and averaged as described in a previous section. Figure 1 shows the variation of the averaged foam height with total gas rate and the dependence of foam height on the total liquid holdup on the tray. High outlet weir heights and high liquid rates correspond to a large liquid holdup. The foam height apparently approaches a maximum at high gas rates. Attempts to predict foam height from a knowledge of the primary operating variables have not been successful, and unfortunately, experimental measurements of foam heights of a given system are necessary at present.

The amount of liquid on the operating tray was measured by manometers installed on the floor of the tray. The height indicated by these manometers is the height to which the foam would collapse if all the air were removed from it, and is called the clear liquid height, Z_c. Like foam height, the height of clear liquid varied from point to point on the tray, and it was therefore necessary to average the point values. These averaged values of clear liquid height decreased regularly as gas rate was increased and, of course, increased as either liquid rate or outlet weir height was increased.

HYDRAULIC GRADIENT

Hydraulic gradients in the active portion of bubble trays manifest themselves as a uniform decrease of both foam height and clear liquid height

along the direction of liquid flow. Although the foam height and the clear liquid height did vary from point to point on the tray, there was no definite and consistent decrease of either of these two in the direction of liquid flow. This was the case for liquid rates up to 70 gal./(min.)(ft.) on trays 18 in. in length. This indicates that the hydraulic gradient, which must exist in order to drive the liquid across the tray, is undetectably small, and that for these flow rates it may be neglected. However, at liquid rates above 100 gal./(min.)(ft.) on tray 45 in. in length, hydraulic gradients up to 0.6 in. were detected from a measured uniform decrease in clear liquid height.

FOAM DENSITY

The height of clear liquid is used in conjunction with the foam height to describe the degree of aeration of the liquid on the tray. The ratio (Z_c/Z_f) is defined as the foam density, ϕ, and is the cubic feet of unaerated liquid per cubic feet of foam. The variation of foam density with total gas rate is shown by Figure 2. This decrease of ϕ with increasing gas rate is such a complicated process that it may be discussed only qualitatively. An increase in gas rate increases the gas content of the foam by increasing the bubble volume or the number of bubbles or both. The rising velocity of the bubbles may also change. Data of Verschoor (*18*) indicate that the rising velocity of bubbles in a gas-liquid mixture of above 40% gas content increases as the gas content increases. Geddes points out that there exists a dynamic balance between this rising velocity and the number of bubbles (*4*). The degree of aeration of the liquid depends on this balance, and at present no means of predicting it has been developed. Foam density also increases slightly with increasing liquid holdup on the tray. The maximum change in foam density is only about 10%, however, if the weir height is changed from the 2-in. value shown in Figure 2 to either 1 or 4 in. The change is almost negligible at gas rates above 4 ft./sec. Because liquid holdup varies with liquid rate as well as with weir height, foam density also varies with liquid rate, but not to any appreciable extent.

It is to be noted that both foam height and foam density have been characterized as functions of the total gas rate. Plots of foam height and foam density vs. the gas velocity through the perforations rather than the total gas rate do not give smooth and continuous curves. The important conclusion to be drawn from these simple foam studies is that the total gas rate rather than the hole velocity is the fundamental operating variable. Because mass transfer characteristics of bubble trays have been found by previous investigations (*3, 6, 7, 15*) to be dependent on the character of the foam, total gas rate should also be the fundamental variable in the mass transfer studies. Analysis of the tray efficiency results has found this to be the case. Use of trays having free areas ranging between 4 and 11% afforded an ample opportunity to study the effect of a wide variation of total gas rate on tray behavior. Air velocity through the perforations of each tray varied over the range 45-65 ft./sec., with the exception of one high velocity of 79 ft./sec. through the 4% free area tray. Because the total gas throughput varies directly as the free area of the tray, an almost fourfold variation of the total gas rate was achieved in these studies.

Liquid-Film Efficiency Results

Liquid-film efficiencies were computed from duplicate measurements of inlet and outlet liquid compositions by Equation (1). The value of the equilibrium concentration, x^*, was evaluated with the use of the literature values of the Henry's law constant (*9*) at the mean temperature of the water on the tray which was maintained between 25 to 30° C. in all of the runs. The change in temperature of the water as it passed over trays 18 in. in length was about 0.5° C., whereas temperature changes as high as 1.2° C. occurred with 36 in. of liquid travel. The two values of efficiency thus obtained for each set of flow conditions agreed excellently with each other, differing usually by less than 2%. All values of efficiencies reported in this work are the averaged values of these duplicate determinations. Experimentally determined efficiencies of the 4, 8, and 11% free area trays are given in Table 2 (A.D.I.).

Liquid-film efficiency was found to decrease strongly with increasing liquid rate at any given gas rate and outlet weir height. This, of course, results primarily from the decreased residence time of the liquid with the gas as the clear liquid rate is increased. Obviously, the longer the liquid is retained on the tray, the greater will be the amount of mass transferred. Figure 3 shows the extent of this variation of efficiency and also the effect of gas rate on tray performance. Behavior similar to this on bubble-cap and tunnel-cap trays has been previously observed and reported (*3, 5, 6, 7, 15*). It is to be noted that the variation of efficiency with gas rate is much more pronounced on the 4% free area tray than on the 11% free area tray. The effects of both gas and liquid rate on efficiency are closely interrelated and their individual effects will be resolved in subsequent discussion.

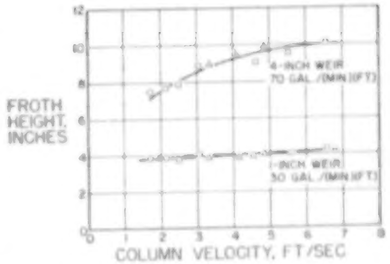


Fig. 1. Variation of froth height with gas rate. Parameters are outlet weir height in inches and clear liquid rate in gal./(min.)(ft. of weir). Circles represent tray having 4.2% free area, triangles represent tray having 8.0% free area, squares represent tray having 10.6% free area.

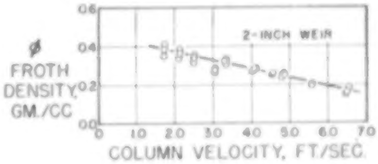


Fig. 2. Variation of froth density with gas rate.

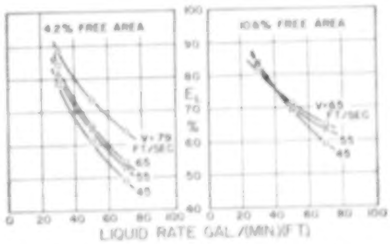


Fig. 3. Typical effect of liquid rate upon liquid-film efficiency. Length of liquid travel is 18 in., outlet weir height is 2 in., and parameter is air velocity through perforations, ft./sec.

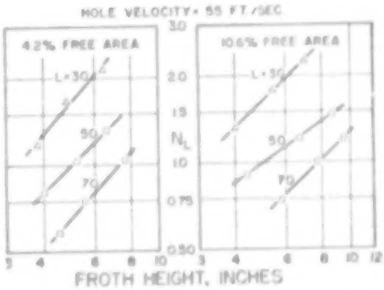


Fig. 4. Dependence of tray performance upon froth height. Length of liquid travel, 18 in. Parameter is liquid rate, gal./(min.)(ft. of weir).

EFFECT OF FOAM HEIGHT ON N_L

Tray performance increased with increase in outlet weir height because liquid residence time increased with weir height. However, residence time depends on the height of the foam rather than on the height of the weir and, for this reason, tray performance is related more fundamentally to foam height than to weir height. Figure 4 shows the typical effect of foam height on tray performance expressed as the number of liquid-film transfer units, N_L. Within the limits of error in foam height measurements, N_L is linear with foam height, and for all practical purposes directly proportional. The proportionality is not exact, however, and the reasons for this will be apparent when the effects of gas and liquid rates are later resolved.

COMPARISON OF TRAYS

In comparing the performance of the 4, 8, and 11% free area trays, one encounters the problem of selecting a set of conditions or characteristics common to all trays upon which a comparison can be based. It was decided to compare the performance of all trays at a constant foam height. Then, even though there may exist a difference in the total foam heights on the trays being compared, this method reduces tray performance to a constant volume of foam. This is advantageous in analyzing the behavior of some of the fundamental factors affecting mass transfer. For example, the total interfacial area present is an important factor affecting tray performance, and this area depends on the total volume of foam on the tray and hence upon the foam height. Comparison of tray performance at a constant foam height permits investigation of the variation of interfacial area per unit volume of foam with changes in the operating conditions.

EFFECT OF GAS RATE ON N_L

Reduction of experimental values of N_L to a given foam height was accomplished by cross-plotting the curves of N_L vs. foam height. Figure 5 is the result of such a cross plot of values of N_L at a froth height of 6 in. for all three trays. A froth height of 6 in. was chosen because it represented a value of froth height intermediate between the extremes measured in these experiments. This figure illustrates the effect of total gas rate on tray performance at various clear liquid rates. Values of N_L in the range of gas rate from 1.7 to 3.1 ft./sec. were obtained on the 4% free area tray only, while the values in the range between 3.4 and 4.8 ft./sec. were obtained on the 8% free area tray. The high gas rate range was investigated by the use of the 11% free area tray.

The most striking characteristic of sieve-tray behavior as described by these curves is the peculiar effect of gas rate on N_L. The number of liquid-film transfer units first increases with increasing gas rate, reaches a maximum corresponding to a maximum in efficiency, and then decreases rapidly at the higher gas rates. The intial increase in efficiency at low gas rates is attributed primarily to an increase in the interfacial area per unit volume of foam. This analysis is substantiated by the behavior of the foam density, ϕ, with gas rate. It is supposed that the amount of interfacial area existing in a unit volume of foam is some function of the gas holdup per unit volume of foam. As the quantity ϕ represents the amount of liquid per unit volume of froth, then $(1-\phi)$ should be a measure of the gas holdup. The quantity $(1-\phi)$ increases with increasing gas rate as indicated by Figure 2, thus producing a greater interfacial area and higher values of N_L. The leveling off and subsequent decrease in tray efficiency with increased gas rate is a consequence of competing effects of changes in interfacial area and residence time of the liquid on the tray. The time of contact of the liquid with the gas has unavoidably been allowed to vary even though foam height and clear liquid rate have been maintained constant in Figure 5. This is apparent when it is noted that the nominal time of liquid residence at a given constant foam height is inversely proportional to the volumetric rate of flow of froth rather than to the volumetric rate of flow of clear liquid. The volumetric froth velocity is (L'/ϕ), that is, the volumetric clear liquid rate divided by the froth density. Since the foam density decreases with increasing gas rate, the froth velocity will increase with gas rate even though the clear liquid rate is constant. Thus, by the maintenance of clear liquid rate and foam height constant as in Figure 5, an increase in gas rate simultaneously increases the interfacial area and decreases the time of residence of the liquid.

Because conclusions concerning the variation of interfacial area and time of contact of the liquid must be deduced from the behavior of N_L, it is necessary first to know the functional relationship between these three quantities before further explanation is attempted. It is assumed that N_L is directly proportional to the interfacial area. Whether N_L is also directly proportional to the time of residence or directly proportional to some fractional power of residence time remains to be proved. This relationship between N_L and residence time must be established before the curves of Figure 5 can be fully explained.

DEPENDENCE OF N_L ON LIQUID RESIDENCE TIME

According to Higbie (*8*) the amount of mass transferred across an interface is proportional to the square root of the time of contact. This result was obtained by considering mass to be transferred by unsteady state diffusion through the liquid film at the interface. The application of this conclusion to mass transfer on an operating tray may be tested by using the present data. The quantity (L'/ϕ) is the volumetric froth flow rate, and it is proportional to the reciprocal of the average time of residence of the liquid with the gas. This is true, of course, only if the foam height is kept constant as the liquid rate is varied. It is realized that due to mixing of the liquid there may be a distribution of residence times for individual elements of liquid ranging from zero to infinity, and that (L'/ϕ) is proportional only to the reciprocal of the average of these various times of residence. Figure 6 is a plot of N_L vs. (L'/ϕ) for the 4% free area tray in which both N_L and ϕ have been corrected to a foam height of 6 in. This plot is typical of all three trays used. The lines are drawn through the points with a slope of -1.0 indicating that more mass has been transferred than had been predicted by the unsteady state diffusion theory. Adherence to this theory would have given the lines a slope of -0.5.

This same nonadherence to Higbie's theory had been found earlier by Gerster, Bonnet, and Hess (*7*). The discrepancy results because Higbie assumed that the liquid film in which concentration profiles are established is undisturbed. Danckwerts (*2*) has proposed that ths film is broken into by masses of liquid from the bulk of the fluid and has derived a surface-age distribution function which depends on the rate of replenishment of surface area. This quantity must be determined by experiment. However, the value of this quantity is not needed in the qualitative discussion of the present data, for the formation of new surface at the interface would give rise, over a period of time, to a time-mean mass-transfer coefficient greater than the one obtained if the films had not been disturbed. This analysis affords a qualitative explanation as to why the mass transferred is dependent on residence time to a power greater than the square root. If the mechanism proposed by Danckwerts is correct, the quantity (L'/ϕ) is by no means a measure of the true time of contact of an element of liquid with the gas-liquid interface. As previously pointed out, the quantity (L'/ϕ) is, however, proportional to the reciprocal of the average residence time of the liquid on the tray. It thus provides

some measure of the contact time, although not a fundamentally correct measurement, and is used in this work only to explain in a semiquantitative manner the behavior of tray performance with variation of the operating variables.

VARIATION OF INTERFACIAL AREA WITH GAS RATE

It is concluded then that the amount of mass transferred on the tray is directly proportional to the nominal time of residence of the liquid with the gas. In view of this finding, reference may now be made again to Figure 5, in which a maximum in N_L occurs. The initial increase in N_L with an increase in gas rate at the low gas rates indicates that the interfacial area is increasing more rapidly than the time of contact is decreasing. At higher gas rates, however, the inverse is true. Since tray performance is directly proportional to both interfacial area and average time of residence, it follows that for a given change in gas rate, the change in interfacial area at low gas rates is greater than the corresponding change at high gas rates. This conclusion is in accord with the observed characteristics of the operating trays. Several jets of gas were observed in the foam on the 11% free area tray whereas the foam on the 4% consisted mostly of evenly dispersed small gas bubbles. It is visualized that an increase of gas rate on a tray where jetting of the gas through the liquid occurs would serve only to increase the size of the jet and hence increase the interfacial area only slightly. When no jetting occurs, an increased gas rate probably increases the number of bubbles and, hence effects a greater increase in the interfacial area. This latter condition corresponds to the low gas rate range of Figure 5.

A means is now available to make a fairer comparison of the performance of the three trays. Rather than comparing tray performance at a given clear liquid rate, tray performance is to be compared at a constant linear froth velocity. This is accomplished by cross-plotting values of N_L from Figure 6 at a constant value of (L'/ϕ). Since these N_L values have already been corrected to a constant foam height, this permits comparison of tray behavior per unit volume of froth per unit of contact time. Then, any variation of N_L with gas rate will be due to the variation in the interfacial area. Figure 7 is the cross plot of N_L values showing the variation of N_L for all three trays at a constant froth velocity of 175 gal. of froth/(min.)(ft. of weir). This graph shows that for a given liquid retention time and height of foam, tray performance continues to increase with increasing gas rate. The important conclusion to be drawn from this result is that this increase in performance is due almost entirely to an increase in interfacial area with increasing total gas throughput.

A continuous line could not be drawn through the entire set of points in Figure 7 because the behavior of the 4% free area tray appears to differ markedly from that of the 8 and 11% free area trays. Each point in this figure is firmly established, and none can be disregarded. The gas velocities through the perforations correspond to 45, 55, and 65 ft./sec. for all points plotted except for one of 79 ft./sec. on the 4% free area tray. The discontinuity at this high hole velocity may invalidate the previous conclusion that total gas rate is the fundamental variable. It should be noted that the previous conclusion concerning the more rapid change in interfacial area on the 4% free area tray is here borne out by the more rapid increase in N_L at the low gas rates, and it should be noted further that there is no maximum value of N_L in this plot as there was in Figure 5 where clear liquid rate rather than linear froth velocity was used as a parameter. This also substantiates the previous conclusion that the maximum in the curves in Figure 5 is due to the competitive effects of changes in interfacial area and time of contact of the liquid with the gas.

VARIATION OF TOTAL TRAY LENGTH

Efficiencies for a tray 36 in. in length were measured for some of the operating conditions used in efficiency measurements on trays 18 in. long. When the liquid flows across the tray without any mixing whatsoever, values of N_L for a given set of operating conditions should be directly proportional to the length of liquid travel, as indicated by Equation (2). Efficiency measurements for the 36-in. tray length were made to determine the extent to which this relationship applies in practice where some liquid mixing on the tray does occur. It was found that the doubling of the tray length from 18 to 36 in. caused an approximately twofold increase in the number of transfer units on the tray. N_L values for both the 18- and 36-in. tray lengths are given in Table 2. To a fair approximation then, performance of trays longer than 18 in. may be computed by using this direct proportionality between N_L and total tray length and the results obtained for the trays 18 in. long. This proportionality is not exact, however, in that N_L values on the 36-in. tray were found to be

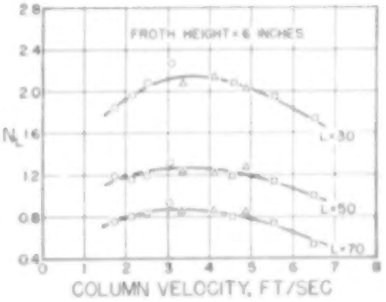


Fig. 5. Typical effect of gas rate upon tray performance at constant froth height. Length of liquid travel is 18 in. Parameter is liquid rate, gal./(min.)(ft. of weir). Circles represent tray having 4.2% free area, triangles represent tray having 8.0% free area, and squares represent tray having 10.6% free area.

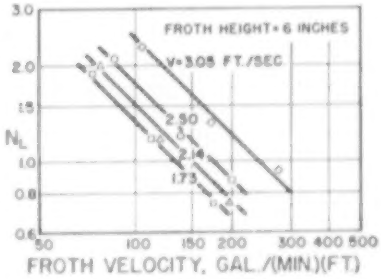


Fig. 6. Typical effect of froth velocity upon tray performance at constant froth height. Parameter is air velocity beneath tray, ft./sec. Length of liquid travel is 18 in. Hole area is 4.2% of active tray area. Values of N_L and ϕ have been corrected to a froth height of 6 in.

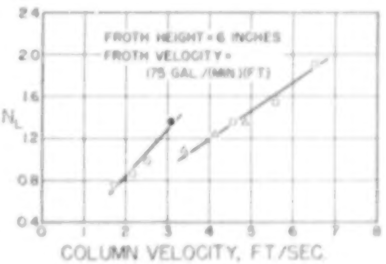


Fig. 7. Effect of gas rate upon tray performance at constant froth velocity and constant froth height. Values of N_L have been corrected to a froth height of 6 in. and to a froth velocity of 175 gal. froth/(min.)(ft. of weir). Length of liquid travel is 18 in. Circles represent tray having 4.2% free area. Triangles represent tray having 8.0% free area. Squares represent tray having 10.6% free area. Solid circle denotes a perforation velocity of 79 ft./sec.

consistently a little greater than twice the corresponding values on the 18-in. tray. This result is caused by the partial mixing of the liquid flowing across the tray and is explained as follows: on large trays, a given liquid eddy may be considered to be of nearly infinitesimal size when compared with the size of the entire tray, but on small diameter trays, an eddy of the same size may constitute a large portion of the tray. One would expect then that the liquid concentration profile and hence the average driving force for mass transfer on large trays would not be greatly altered by mixing, whereas the average driving force on small trays could be more easily altered. Thus, by increasing the tray length from 18 to 36 in., not only is the time of contact of the liquid with the gas increased, but also the adverse effects of liquid mixing upon the average driving force and hence upon the tray performance are minimized to some extent.

It is reasonable, then, that the N_L values obtained on trays 36 in. long were found to be somewhat larger than twice the N_L values observed for trays 18 in. long. These conclusions concerning liquid mixing are only qualitative; additional experimental techniques must be employed in order to obtain a quantitative measure of the degree of mixing. Studies of the degree of liquid mixing and its effect on plate efficiency are currently being continued at the University of Delaware laboratories.

Gas Pressure Drop

The pressure drop of the air passing through the perforations and through the aerated liquid flowing across the tray increased with increase of gas and liquid rates and outlet weir height in the same manner as found by Mayfield *et al.* (*12*) in their sieve-tray studies. Gas pressure drop through the dry tray with no liquid flowing was found to be independent of free area, and proportional to the gas velocity through the perforations raised to the power 2.06. The orifice coefficient, C, in the equation $v_o = C(2g_c\Delta h)^{1/2}$ was found to be 0.77 for these trays.

It was supposed that the total pressure drop of an operating tray would consist of the sum of the dry tray drop and the clear liquid holdup on the tray. The experimental results indicate, however, that the sum of the dry pressure drop and the clear liquid holdup is as much as 25% less than the total gas pressure drop. This phenomenon has also been reported by Arnold *et al.* (*1*) and by Mayfield *et al.* (*12*). Because the magnitude of this pressure-drop discrepancy depends upon the liquid holdup and upon gas rate, there is reason to believe that a complicated, dynamical behavior of the liquid in the vicinity of the forming bubble is responsible for the observed discrepancies. It is possible that liquid fills a portion of the perforation during operation with liquid flow. This would necessitate a higher perforation velocity and produce a higher gas pressure drop through the hole than would be obtained if the plate were dry.

Conclusion

The most important fundamental factors affecting liquid-film plate efficiency were found to be the total amount of interfacial area available within the froth and the time of contact of the liquid with the gas. Experimental results indicate that the amount of interfacial area per unit volume of froth continues to increase as the total gas throughput is increased. This finding is important because it indicates that tray performance depends upon the total gas throughput rather than upon the velocity of the gas through the perforations. It was further found that tray performance expressed as the number of liquid-film transfer units is directly proportional to the nominal time of contact of the liquid with the gas. The establishment of these conclusions was greatly facilitated by use of the froth height and the froth density as correlating variables and as quantities to describe the physical nature of the froth.

Acknowledgment

This investigation was carried out under the sponsorship of the Federal Facilities Corporation, Office of Synthetic Rubber, in connection with the government's synthetic rubber program.

Notation

C = orifice coefficient for perforations in tray

E_L = liquid-film plate efficiency

g_c = conversion constant, $\frac{\text{(ft.)(lb.mass)}}{\text{(lb.force)(sec.)(sec.)}}$

Δh = gas pressure drop across dry tray, ft. of gas flowing

k_La = liquid-film mass transfer coefficient, lb. moles/(hr.)(cu.ft.)(unit mole fraction difference)

L = molar liquid rate, lb. moles/(hr.)(sq. ft. of active tray cross-section)

L' = volumetric liquid rate, gal./(min.)(ft. of weir length)

N_L = number of liquid-film transfer units

ΔP = gas pressure drop across tray, in. of water

v_o = linear velocity of gas through individual perforations in tray, ft./sec.

x = mole fraction of solute in liquid phase at any point on tray

x^* = equilibrium mole fraction of solute in liquid phase

x_1, x_2 = mole fraction of solute in liquid phase at liquid inlet and outlet respectively

Z = horizontal distance along aerated portion of tray up to point in question; measured from liquid inlet of aerated portion, ft.

Z_c = height of clear liquid on operating tray, ft.

Z_f = height of aerated liquid above tray floor, ft.

Z_H = total horizontal distance on plate in direction of liquid flow over which liquid is contacted with gas, ft.

ϕ = density of aerated mass of liquid on tray, computed as Z_c/Z_f, g./cc.

Literature Cited

1. Arnold, D. S., C. A. Plank, and E. M. Schoenborn, *Chem. Eng. Progress*, **48**, 633 (1952).
2. Danckwerts, P. V., *Ind. Eng. Chem.*, **43**, 1460 (1951).
3. Field, J., "Performance of a Tunnel Cap Tray," M. Ch.E. Thesis, University of Delaware (1952).
4. Geddes, R. L., *Trans. Am. Inst. Chem. Engrs.*, **42**, 79 (1946).
5. Gerster, J. A., A. P. Colburn, W. E. Bonnet, and T. W. Carmody, *Chem. Eng. Progress*, **45**, 716 (1949).
6. Gerster, J. A., W. E. Bonnet, and I. H. Hess, *Chem. Eng. Progress*, **47**, 523 (1951).
7. Gerster, J. A., W. E. Bonnet, and I. H. Hess, *Chem. Eng. Progress*, **47**, 621 (1951).
8. Higbie, R., *Trans. Am. Inst. Chem. Engrs.*, **31**, 365 (1935).
9. International Critical Tables, **3**, 257 (1929).
10. Jones, J. B., and C. Pyle, *Chem. Engr. Progress*, **51**, 424 (1955).
11. Kamei, S., and T. Takamatsu, *Memoirs of the Faculty of Engr., Kyoto University*, **XV**, No. 2 (April, 1953).
12. Mayfield, F. D., W. L. Church, A. C. Green, D. C. Lee, and R. W. Rasmussen, *Ind. Eng. Chem.*, **44**, 2238 (1952).
13. Nandi, S. K., and B. Karim, *J. Indian Chem. Soc., Ind. News Ed.*, **11**, 12 (1948).
14. Perry, J. H., "Chemical Engineers' Handbook," 3 ed. McGraw-Hill Book Co., Inc., New York (1950).
15. Remer, N. A., "Effects of Bubble Tray Design on Plate Efficiency," M.Ch.E. Thesis, University of Delaware (1954).
16. "Standard Methods for the Examination of Water and Sewage," 9 ed., Am. Public Health Assn., New York (1946).
17. Stone, H. L., "Mass Transfer on Bubble Cap and Perforated Plates," Dr. S. Thesis, M.I.T. (1953).
18. Verschoor, H., *Trans. Inst. Chem. Engrs.* (London), **28**, 52 (1950).
19. West, F. B., W. D. Gilbert, and T. Shimizu, *Ind. Eng. Chem.*, **44**, 2470 (1952).

Presented at A.I.Ch.E. Springfield, Massachusetts, meeting.

A STUDY OF

retention time in a rotary dryer

Ford Miskell — Research Laboratories, Allis-Chalmers Manufacturing Company

W. R. Marshall, Jr. — University of Wisconsin

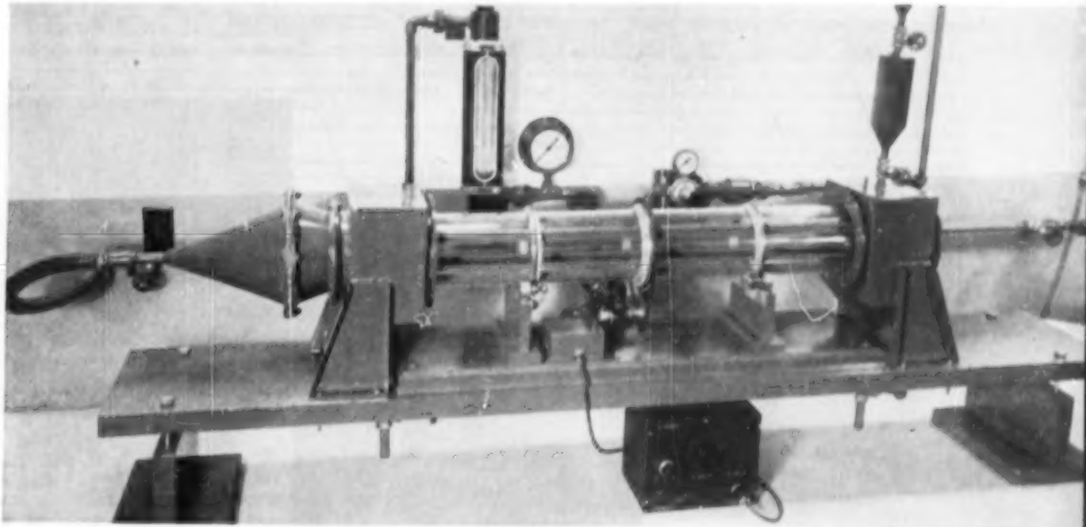


Fig. 1. Experimental dryer.

The deviation from the average time of passage of solid particles as they pass through a rotary dryer has been investigated. This was done with the aid of a radioactive tracer added to the dryer feed and continuously monitored in the dryer product. Results indicated that for the dryer-flight design studied the deviation from the average retention time was a minimum at a dryer holdup of 7.5 to 8% and that above or below this holdup the deviation increased.

Many types of solids-handling devices have been adapted to the drying of solids. In some types, such as a tunnel dryer, each solid particle is retained in the drying chamber for precisely the same length of time as is every other particle. In other types, such as a fluidized solids column, some particles may be retained for only a fraction of a second while other particles may be retained for several minutes.

The retention of all particles in a dryer for the same length of time implies a degree of uniformity in the treatment. Conversely, when solid particles become dispersed within a dryer, some particles, retained for a relatively long time, may be overdried and overheated and others, retained for a shorter period, may be underdried.

The case of a radial-flight rotary dryer is intermediate between the extreme cases cited above with respect to the degree to which feed particles become dispersed in passing through the dryer. A more important distinction is that in the case of a rotary dryer some control over the degree of dispersion may be had through control of the dryer loading and possibly other variables. The object of this investigation was to study the effect of dryer loading on the degree to which solid particles became dispersed.

Procedure Used in This Study

DRYER

The dryer shell employed in this investigation is shown in Figure 1. It had a 5.5 in. I.D. and a length of 40 in. Six radial flights extended the entire length of the dryer, and were equally spaced around the circumference. Each flight was 0.75 in. high. A lip, 0.25 in. high, was attached at right angles to the edge of each flight. Previous work had established the fact that the material-handling characteristics of this model were very similar to those of rotary dryers of larger scale. Feed rate, dryer speed and slope were correlated with

holdup. These results, shown on Figure 2, are in excellent agreement with those of another investigation (*1*) in which the material-handling characteristics of a 1-ft. diam. dryer were studied. The correlation is, in fact, identical.

MATERIAL

The dryer feed consisted of a coarse-grained, closely sized silica sand with a mass median particle size of 496 μ, approximately equivalent to U. S. Standard No. 35-mesh. The radioactive tracer material was prepared by dissolving one part of uranyl nitrate in water, mixing the solution with four parts of the silica sand, and carefully evaporating the water of solution while the mixture was agitated. This technique caused each sand grain to acquire a coating of the uranium salt which proved to be resistant to abrasion. The coated sand had a mass median particle size of 551 μ, approximately equivalent to U. S. Standard No. 30-mesh.

INSTRUMENTATION

With reference to Figure 3, silica sand which discharged from the dryer was deposited on a conveyer belt driven by a variable speed motor. A Geiger-Mueller tube was secured to the underside of the conveyer such that the tube was about 1 in. above the sand on the belt. The Geiger-Mueller tube was connected to a recording milliammeter and an oscillograph, as shown in Figure 4.

OPERATION

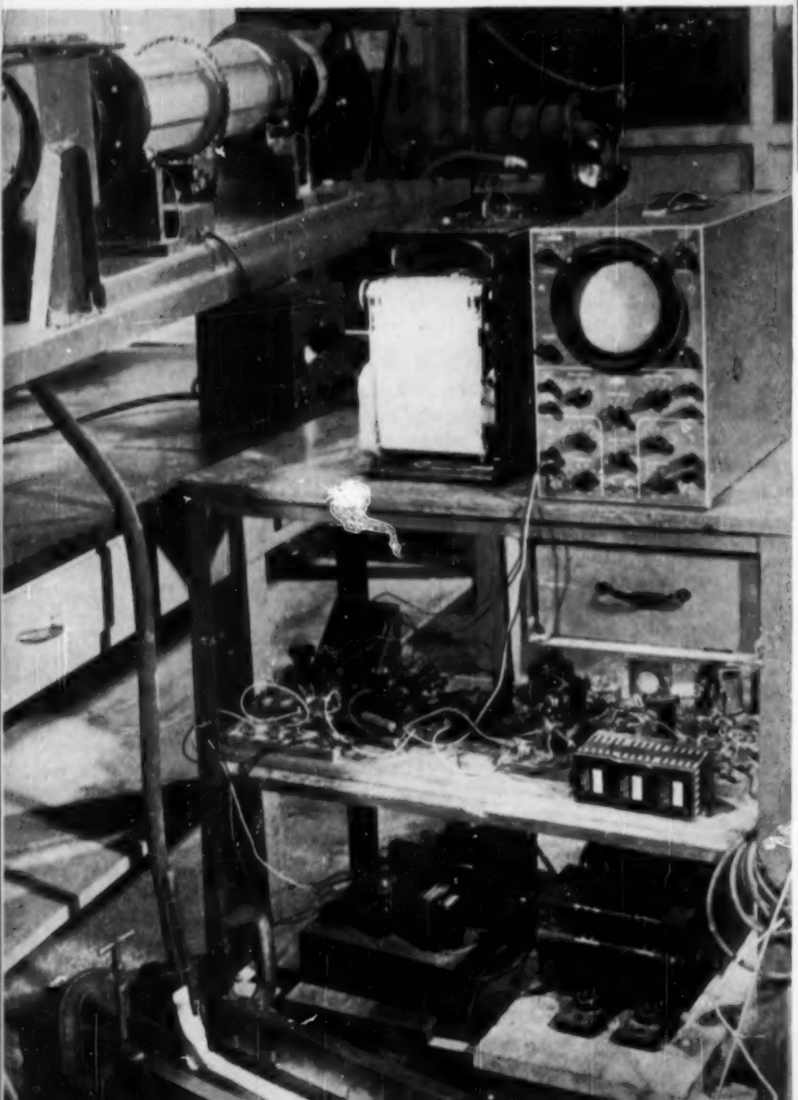
In each of the six experiments, equal volumes of pure silica sand were fed to the dryer at regular intervals, usually 15 sec., for a length of time sufficient to insure equality of feed and discharge rates. This procedure gave a more accurately controlled feed rate over a wide range than would have been obtainable with continuous laboratory-scale feeders. When equilibrium conditions had been established, a small quantity of the radioactive particles was introduced. Silica sand was then fed to the dryer as before until all of the tracer had passed out of the dryer and under the G-M tube. The true end point was taken as that time at which the output of the G-M tube could be attributed entirely to background radiation. The time lag corresponding to the interval required for a particle to leave the dryer and pass under the G-M tube was measured. At the end of each experiment the holdup in the dryer was collected in a separate container and its volume determined.

In these six experiments the dryer slope and speed were held constant at 0.03 ft./ft. and 6 rev./min., respectively. The feed rate was varied from 0.246 to 2.51 cu.ft./sq.ft. of dryer cross-section per hour in order to obtain holdups from 1.00 to 10.7% of the dryer volume.

Results

For each experiment a curve showing the history of the tracer concentration in the dryer product was obtained from the recording milliammeter. One such curve is shown in Figure 5. The horizontal portion of the curve at the extreme left of the figure corresponds to the zero setting before the tracer arrived at the monitoring point. The small fluctuations in this portion of the curve

Fig. 3. Equipment used for radioactivity analyses.



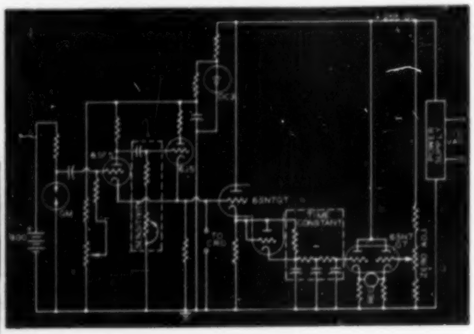


Fig. 4. Electrical circuitry for retention-time study.

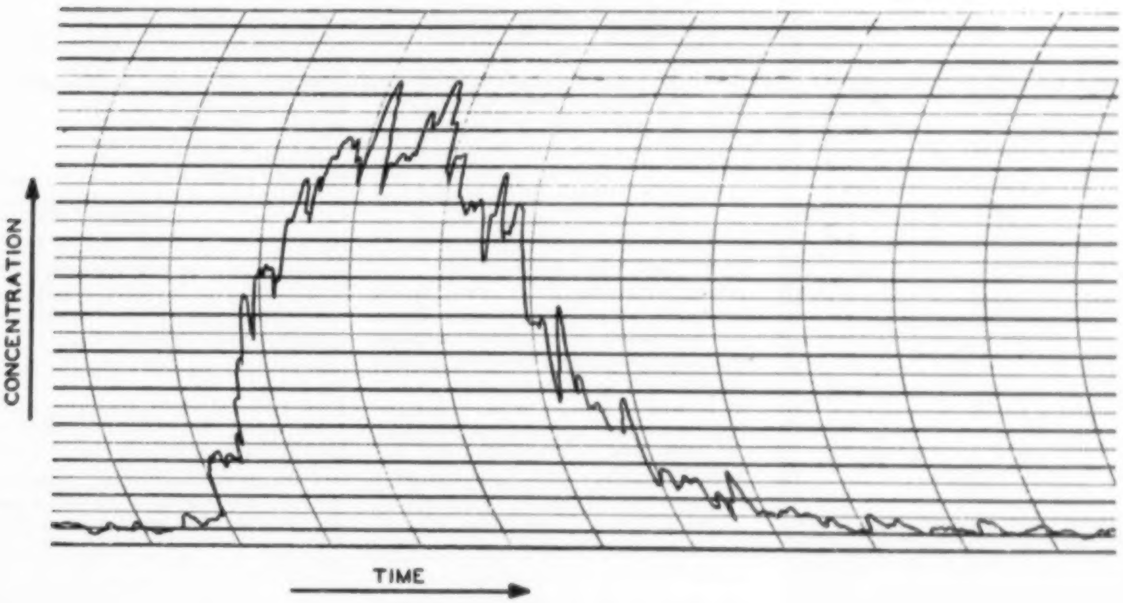


Fig. 5. Tracer concentration vs. time.

were attributed to background radiation. It may be seen that the concentration of tracer in the dryer product increased sharply to a maximum and then decreased more slowly. The general shape of this curve could be predicted from statistical considerations. The rapid rise of the curve was anticipated because the interval between the time the tracer was added to the dryer and the time at which maximum tracer concentration was indicated by the G-M tube could not exceed the sum of the mean retention time in the dryer and time required for the dryer product to travel along the conveyer and pass under the G-M tube. On the other hand, there was no theoretical limit to the length of time required for the last particle of tracer to leave the dryer and so it was expected that the tracer concentration curve would decline more slowly. The irregularities in the upper portion of the curve reflect variations in tracer concentration with time superimposed on the over-all pattern. It was possible to increase the magnitude of these major irregularities or to damp them out almost completely by altering slightly the components of the electric circuit which controlled the time constant as shown in Figure 4. From Figure 5 it might be argued that the tracer concentration curve does pass through two maxima as proposed by Saeman and Mitchell (*4*). However, an inspection of all the curves obtained in this investigation led to the conclusion that no more than one maximum can consistently be recognized.

Cumulative time curves of the type shown in Figure 6 were constructed from the tracer concentration curves (Figure 5) with the aid of a planimeter. Arithmetic probability paper was found most suitable for this type of plot because it permitted an easy estimate of the standard deviation as a measure of the dispersion of the tracer within the dryer. The standard deviation in minutes was obtained from plots similar to that shown in Figure 6 for each experiment by finding the difference in the times required for 50 and 84.13% of the tracer to discharge from the dryer. The time at which the tracer entered the dryer was taken as zero. This standard deviation was then di-

Table 1.—Experimental Results

Exp. No.	Dryer slope ft./ft.	Dryer speed rev./min.	Feed rate cu.ft./sq.ft./hr.	Holdup %	Relative standard deviation %
1	0.03	6	0.246	1.00	19.0
2	0.03	6	0.615	3.06	12.3
3	0.03	6	1.01	5.24	8.48
4	0.03	6	1.42	6.88	6.55
5	0.03	6	2.08	9.73	7.43
6	0.03	6	2.51	10.70	8.17

FIGURE 2

GENERAL MATERIALS HANDLING CORRELATION FOR RADIAL FLIGHT DRYER

NO AIR FLOW

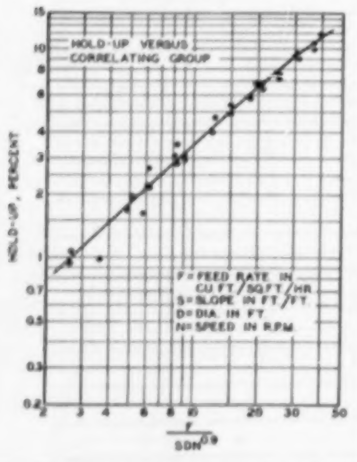


FIGURE 6

PERCENT OF TRACER OUT OF DRYER VERSUS TIME

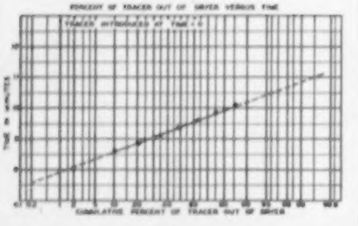
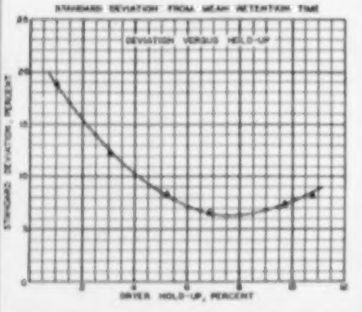


FIGURE 7

STANDARD DEVIATION FROM MEAN RETENTION TIME



vided by the time required for 50% of the tracer to discharge from the dryer in order that the results of the several experiments could be compared directly even though the mean retention time varied slightly over the series. This quotient, termed the relative standard deviation, was reported on a percentage basis and is listed with recorded data from the experiments in Table 1.

The relative standard deviations presented in this table are a function only of the dryer holdup. It is possible that the same value of holdup could be obtained from several sets of conditions of dryer speed, slope, and feed rate. It is probable that the dryer speed would have an effect on retention time deviation at constant holdup. This possibility was not investigated; however, it does not detract from the value of the results of this study because dryer speed and slope were held constant for the series of experiments.

The retention time relative standard deviation was plotted vs. dryer holdup as shown in Figure 7. It may be seen that at low holdup the deviation is high, probably as a result of excessive bouncing of particles as they strike the bare dryer shell. The deviation passes through a minimum at approximately 7.5 to 8% loading and increases again at higher loadings. The increase at higher loadings is attributed to overloading of the lifter flights which causes some of the feed to pass rapidly through the dryer in the same manner that it does through a rotary kiln.

EXTRAPOLATION TO OTHER FLIGHT DESIGNS

It should be emphasized that the general form of this curve is probably applicable only to radial-flight rotary dryers. It is anticipated that the position of the curve might be shifted somewhat by alteration of the flight arrangements and the number of flights. The value of dryer holdup yielding minimum retention time deviation would probably be proportional to the carrying capacity of the flights regardless of whether carrying capacity was altered by changing the number of flights or their dimensions.

Previous Work

In recent years some experimental studies have been reported in the literature regarding the materials-handling aspect of rotary dryers. Significant among these contributions has been the development of empirical expressions relating holdup (defined as the quantity of material in a dryer at equilibrium) to variables such as dryer speed and slope, feed rate of solids, and gas velocity (*1, 3, 4*). The average time of passage of solids through a rotary dryer is usually computed by dividing the equilibrium holdup in the dryer by the feed rate. The retention time so calculated is useful for the prediction of dryer slope, the study of dryer performance. However, it must be appreciated that the time of passage of an individual particle of feed may deviate greatly from the calculated average value. This deviation from the average retention time can be a principal cause of nonuniformity of product quality and should, therefore, be minimized.

Several investigators have studied the statistical nature of the time of passage of solids through rotary dryers. Smith (*5*) described an experiment in which a quantity of soda ash was added to a dryer feed. The product was sampled periodically and the samples were analyzed for alkalinity by titration with hydrochloric acid. The results were presented graphically as soda-ash concentration in the product samples, plotted on the ordinate, vs. time, plotted on the abscissa. A curve was obtained which rose sharply to a maximum and then decayed slowly. This technique has two apparent drawbacks: first there is no assurance that the soda ash passes through the dryer at the same rate as does the dryer feed, and second the curve showing retention-time distribution must necessarily be constructed from a limited number of data points.

A similar experiment was reported by Gardner, *et al.* (*2*) in which a radioactive chemical, absorbed by a portion of the feed to a rotary louver-type dryer, was employed as a tracer. This refinement insured that the physical characteristics of the tracer and the dryer feed would be identical. However, these investigators chose to analyze individual product samples for radioactivity and consequently their curve showing concentration of tracer vs. time was also constructed from limited data.

Saeman and Mitchell (*4*) approached the statistical nature of time of passage from a purely theoretical viewpoint. Consideration of the paths followed by particles falling from the several flights within a dryer led them to conclude that if the concentration of a tracer in the dryer product is plotted vs. time, a curve exhibiting two maxima should result. In an effort to support this conclusion, they suggested that a curve exhibiting two maxima could be drawn through the data points presented by Smith (*5*).

Acknowledgment

The investigation detailed in this paper was conducted in the research laboratories of the Allis-Chalmers Manufacturing Company. The assistance of William Lindsay and John Borek of these Laboratories is acknowledged with thanks.

Literature Cited

1. Friedman, S. J., and W. R. Marshall, Jr., *Chem. Eng. Progr.*, **45**, 482 (1949).
2. Gardner, R. G., T. J. Mitchell, and R. Scott, *Chem. & Ind.*, p. 448 (1952).
3. Prutton, C. F., C. O. Miller, and W. H. Schuette, *Trans. Am. Inst. Chem. Engrs.*, **38**, 841 (1942).
4. Saeman, W. C., and T. R. Mitchell, *Chem. Eng. Progr.*, **50**, 467 (1954).
5. Smith, B. A., Written discussion to Literature Cited (3).

Presented at A.I.Ch.E. forty-eighth annual meeting, Detroit, Michigan.

CEP ANNUAL GUIDE

TO PERTINENT CHEMICAL ENGINEERING RESEARCH THESES

Each listing below represents a University Ph.D. thesis.

ABSORPTION

A Study of Rate Factors for a Mechanically Agitated Gas-Liquid Contactor. WILLIAM OVERTON, Ohio State University. Prof. Aldrich Syverson, 173 pp. One copy available from University Library. Separate abstract available in 1957. (August, 1955.)

ADSORPTION

Selective Adsorption of Aromatic Liquids.* E. RICHARD SCHMELZER, University of Pennsylvania. Prof. M. C. Molstad and Prof. P. F. Hagerty, 134 pp. One copy available from University Library. (June, 1955.)

AEROSOLS

Particle Size Distribution from Angular Variation of Intensity of Forward-Scattered Light.* JIN HAM CHIN, University of Michigan. Prof. C. M. Sliepcevich, 180 pp. One copy available in General Library of University. Positive microfilm 0.01¼ ct. per page. Abstract and conclusions published in "Microfilm Abstracts." (1955.)

A Rapid Technique for Determining Specific Surface in Liquid-Liquid Sprays.* RICHARD H. BOLL, University of Michigan. Prof. C. M. Sliepcevich, 224 pp. One copy available in General Library of School. Positive microfilm 0.01¼ cts. per page. (1955.)

CHEMICAL PROCESS

The Chemical Actions of the Current Path of Synchronous Electrode. ROBERT E. KELLY, University of Texas. Prof. E. P. Schoch, 158 pp. Two copies filed in University Library. (January, 1955.)

An Economical System of Concentrating Dilute Acetylene Gases. RUBEN P. LIGHTFOOT, University of Texas. Prof. E. P. Schoch. Two copies available from University Library. (June, 1955.)

Effect of Fluid Density on the Fluidization of Solids. ROBERT L. RICHARDS, JR., M.I.T. Profs. W. K. Lewis and E. R. Gilliland, 437 pp. Filed in Hayden Library of M.I.T. Photostats and microfilm available from Hayden Library. (February, 1955.)

Hydrogenation with Chromium Oxide Catalysts.* DAVID MILLER, Illinois Institute of Technology. Prof. V. I. Komarewsky, 150 pp. Two copies available from school. (June, 1955.)

A Pilot-Plant Study of the Oxidation of Ammonia to Nitrous Oxide.* CHARLES M. OUALLINE, University of Texas. Prof. K. A. Kobe, 96 pp. Two copies on file at the University. (February, 1955.)

Polymerization of Ethylene Initiated by Gamma Radiation.* JAMES C. HAYWARD, JR., Yale University. Prof. Randolph H. Bretton, 268 pp. Two copies filed in University Library. (June, 1955.)

The Progressive Stages of Synchronous Electrode and the Physical Actions Determining Its Current Path. CLYDE E. PARISH, JR., University of Texas. Prof. E. P. Schoch, 148 pp. Copies for loan filed in school library. (January, 1955.)

Recovery of Aconitic Acid from Molasses. ERNEST A. REGNA, Polytechnic Institute of Brooklyn. Prof. Paul F. Bruins, 184 pp. One copy available from Spicer Library of the school. (June, 1955.)

Rubber-Filler Interactions. EDGAR B. GUTOFF, M.I.T. Prof. E. R. Gilliland, 260 pp. Photostats and microfilm available from M.I.T.'s Hayden Library. (September, 1954.)

Semichemical Pulps by Continuous Methods. MARSHALL FINDLEY, University of Florida. Prof. W. J. Nolan, 110 pp. One copy available from Engineering Library of University. Photostates 25 cts. a page plus $1.00; microfilm $4.40. (June, 1955.)

A Study of the Hargreaves Reaction to Produce Sodium Sulfate from Sodium Chloride in a Fluidized Salt Bed.* JOHN L. GIDLEY, University of Texas. Prof. K. A. Kobe, 151 pp. Two copies filed in University Library. (June, 1955.)

The Synthesis of Pinic Acid. PAUL O. PFEUFFER, Polytechnic Institute of Brooklyn. Prof. Donald F. Othmer, 122 pp. Abstracts available separately. One copy on file in school library. (June, 1955.)

COMBUSTION

Boundary-Layer Effects in Bluff-Body Flame Stabilizers.* PANG TSU WOO, M.I.T. Profs. H. C. Hottel and G. C. Williams, 167 pp. Photostats and microfilm available from M.I.T.'s Hayden Library. (September, 1955.)

Reaction Rates in Enclosed Turbulent Flames. HERMANN E. VON ROSENBERG, University of Delaware. Profs. C. W. Shipman and Kurt Wohl, 184 pp. (June, 1955.)

CORROSION

Polarization Characteristics of Aluminum and Stainless Steel in Fuming Nitric Acid and Their Application to Corrosion. SAUL BARRON, Ohio State University. Prof. Webster B. Kay, 136 pp. One copy on file in school library. (March, 1955.)

DIFFUSION

Diffusion in Binary Liquid Mixtures.* WILLIAM SCHOTTE, Columbia University. Prof. T. B. Drew, 137 pp. Copy may be seen in Essay & Dissertation Office of Columbia. Photostat 10 cts. per page; microfilm 1.25 cts./page. (1954.)

Diffusion and Chemical Reaction in Porous Catalysts.* CLEMENT W. BOWEN, JR., University of Pennsylvania. Prof. P. F. Hagerty, 196 pp. One copy available for loan from Main library of school. (February, 1955.)

The Effect of Orientation and Association in Thermal Diffusion.* WALTER S. KMAK, University of Illinois. Prof. H. G. Drickamer, 123 pp. Two copies on file in university library. Microfilm available at 0.01¼ cts./page. (November, 1955.)

High Pressure Properties of Polymer Solutions.* ALDEN E. EMERY, JR., University of Illinois. Prof. H. G. Drickamer, 223 pp. Two copies on file in university library. Microfilm available at 0.01¼ cts./page. (December, 1954.)

Interferometric Study of Molecular Diffusion in Binary Liquid Systems.* COLIN S. CALDWELL, University of Washington. Prof. A. L. Babb, 170 pp. Two copies filed with library of school. Microfilm 3 cts./page. (January, 1955).

Rates of Flow Through Microporous Solids. JOSEPH L. RUSSELL, M.I.T. Profs. E. R. Gilliland and R. F. Baddour. Photostats and microfilm available from M.I.T.'s Hayden Library. (September, 1955.)

Self-Diffusion in Liquids: Concentration Dependence in Binary Solutions.* PAUL A. JOHNSON, University of Washington. Prof. A. L. Babb, 221 pp. Two copies on file in school library. Microfilm available .03 cts./page. (May, 1955.)

Thermal Diffusion of a Coal Tar Pitch.* JOHN T. CUMMING, Case Institute of Technology. Prof. Thomas J. Walsh, 43 pp. One copy available from Case Institute. Microfilm $1.50. (June, 1955.)

Thermal Diffusion in Metals.* FREDRICK R. WINTER, University of Illinois. Prof. H. G. Drickamer, 76 pp. Two copies on file in school library. Microfilm available from University Microfilms, Ann Arbor, at 0.01¼ cts./page. (July, 1955.)

DISTILLATION

Capacity Factors in the Performance of Perforated-Plate Distillation Columns.* CHARLES d'A. HUNT, University of California. Prof. D. N. Hanson, 151 pp. One copy on file in school library. Photostat $9.82; microfilm $5.29. (June, 1955.)

Distillation Calculations Using a High-Speed Digital Computer.* JOHN F. O'DONNELL, M.I.T. Prof. E. R. Gilliland, 553 pp Photostats and microfilm available from M.I.T.'s Hayden Library. (June, 1955.)

A Mathematical Investigation of the Problem of Transients and Control in a Distillation Column.* THEODORE J. WILLIAMS, Pennsylvania State University. Prof. Arthur Rose, 589 pp. Copies available from the university Walker Laboratory. Abstracts available separately. (June, 1955.)

Plate Efficiencies for Absorption and Desorption in a Bubble-Cap Column.* LAWRENCE A. WARZEL, University of Michigan. Prof. Brymer Williams, 229 pp. Copy available from General Library of school. Positive microfilm 0.01¼ cts./page. (1955.)

Selective Solvents for Use in Paraffin-Olefin Separations.* JOHN A. GORTON, University of Delaware. Prof. J. A. Gerster, 78 pp. One copy on loan at Memorial Library of school. (June, 1955.)

A Study of Overall Plate Efficiency in 1.83 and 3 inch Diameter Perforated Plate Distillation Columns.* CHARLES L. UMHOLTZ, University of Texas. Prof. M. Van Winkle, 88 pp. One copy available in school library. (June, 1955.)

A Study of the Performance Characteristics of the Valve-Type Perforated Tray.* ROBERT N. MADDOX, Oklahoma A. & M. College. Prof. C. L. Nickolls, 147 pp. One copy for loan at school library. (October, 1954.)

EXTRACTION

The Extraction of Iron, Cobalt, and Nickel Sulfates.* CARL SCHLEA, Ohio State University. Prof. C. J. Geankoplis, 151 pp. Copies for loan available in school library. (March, 1955.)

Flooding Characteristics of a Pulse Column.* ROBERT B. EDWARDS, Iowa State College. Prof. G. H. Beyer, 85 pp. Copies available for loan from school library. Photostats 35 cts./page; microfilm 0.02½ cts./page.

The Influence of Interfacial Tension on the Breakup of a Liquid into Liquid Jet.* ROBERT M. CHRISTIANSEN, University of Pennsylvania. Prof. A. N. Hixson, 123 pp. One copy available for loan from school library. (June, 1955.)

Mass Transfer with Chemical Reaction.* JAMES C. WEI, M.I.T. Prof. T. K. Sherwood, 176 pp. Photostats and microfilm available from M.I.T.'s Hayden Library. (June, 1955.)

Operating Characteristics of a Centrifugal Extractor. FREDERICK M. JACOBSEN, JR., Iowa State College. Prof. G. H. Beyer, 134 pp. Copies available for loan from college library. Photostat 35 cts./page; microfilm 0.02½ cts./page. (December, 1954.)

Recovery of Uranium from Slag from the Electric Furnace Production of Phosphorus.* HOBART Z. CAMMACK, Iowa State College. Prof. G. L. Bridger, 159 pp. Not available. (August, 1955.)

Recovery of Uranium from Superphosphate.* ARTHUR W. ANDRESEN, Iowa State College. Prof. G. L. Bridger, 123 pp. Copies available for loan from school library. Photostats 35 cts./page; microfilm 0.02½ cts./page. (June, 1955.)

Separation of Monoglycerides, Diglycerides, and Triglycerides by Liquid-Liquid Extraction. JOHN A. MONICK, New York University. Prof. Robert E. Treybal, 94 pp. (March, 1955.)

Studies of the Separation of Titanium and Iron Sulfates.* EDGAR N. BRIGHTBILL, University of Pennsylvania. Prof. A. Norman Hixson, 189 pp. One copy available for loan from school library. (February, 1955.)

FERMENTATION

Multi-Tank Continuous Fermentation. JOSEPH E. NOWREY, University of Illinois. Prof. R. K. Finn, 92 pp. Two copies available from school library. Microfilm available from University Microfilms at 0.01¼ cts./page. (August, 1955.)

FILTRATION

Prediction of Filtration Resistance by Compression-Permeability Techniques.* FRANK A. KOTTWITZ, Iowa State College. Prof. D. R. Boylan, 291 pp. Two copies available from school library. Photostats 35 cts./page; microfilm .02½ cts./page. (June, 1955.)

FLOTATION

The Study of Flotation on Taconites. KALYANJI U. PATEL, Michigan State University. Prof. Clyde C. DeWitt, 73 pp. One copy filed in school library. (1954.)

FLUIDIZATION

Effect of Solids Flow Rate and Particle Diameter on Pressure Drop in Pneumatic Transport Systems. NANALAL G. MEHTA, Purdue University. Profs. J. M. Smith and E. W. Comings, 148 pp. Loan copies available from school library. Photostats 20 cts./page; microfilm .07½ cts. ea. for first 100 frames (about 2 pages). (January, 1955.)

Effect of Turbulence on Drop Size for an Oil-Water Dispersion. PAUL H. ROY, Illinois Institute of Technology. Prof. J. Henry Rushton, 147 pp. Not available for loan. (March, 1955.)

Entrainment from Fluidized Beds. PETER M. LANG, M.I.T. Profs. W. K. Lewis and E. R. Gilliland, 283 pp. Photostats and microfilm available from M.I.T.'s Hayden Library. (September, 1955.)

The Flow of Wood Pulp Slurries.* ROBERT J. RICHARDSON, M.I.T. Prof. J. E. Vivian, 353 pp. Photostats and microfilm available from M.I.T.'s Hayden Library. (September, 1954.)

Interaction of Mass and Momentum Transfer in Turbulent Boundary Layers.* ROBERT S. DAVIS, M.I.T. Prof. H. S. Mickley, 144 pp. Photostats and microfilm available from M.I.T.'s Hayden Library. (June, 1955.)

Momentum Transfer for Flow Over a Flat Plate with Blowing and Main Stream Acceleration.* ADOLF W. GESSNER, M.I.T. Prof. H. S. Mickley, 185 pp. Photostats and microfilm available from M.I.T.'s Hayden Library. (September, 1954.)

The Transient Behavior of a Two-Phase Natural Convection Loop.* EUGENE H. WISSLER, University of Minnesota. Profs. N. R. Amundson and H. S. Isbin, 105 pp. Copies not available on loan. (June, 1955.)

HEAT TRANSFER

Accommodation Coefficients and Thermal Conductivities of Gases at Reduced Pressures.* JOSEPH D. LOKAY, Illinois Institute of Technology. Prof. Ralph E. Peck, 80 pp. Not available for loan. (June, 1955.)

Analysis of Heat Transfer and of Mass Transfer in Turbulent Streams. JOHN F. PARDO, Columbia University. Prof. Thomas B. Drew, 222 pp. Photostats 10 cts./page; microfilm 25 cts./page. Copies not available until after January 31, 1957. (1954.)

Annular Orifice Coefficients with Application to Heat Exchanger Design.* KENNETH J. BELL, University of Delaware. Prof. O. P. Bergelin, 153 pp. One copy available for loan. (June, 1955.)

Condensation Heat Transfer Inside Horizontal Tubes.* O. K. CROSSER, Rice Institute. Prof. W. W. Akers, 93 pp. One copy on file in library of school. (May, 1955.)

Cooling and Dehumidification of Air by a Finned Tube.* BROUGHTON L. BAKER, North Carolina State College. Prof. K. O. Beatty, Jr., 85 pp. One copy filed in school library. (June, 1955.)

Effect of Gas Entrainment on the Heat Transfer Characteristics of Mercury under Turbulent Flow Conditions. HAROLD CHELEMER, University of Tennessee. Prof. R. M. Boarts, 164 pp. Copies available for loan in university library. (June, 1955.)

Effect of Gas Temperature Gradients on Radiant Heat Transmission. EDWARD S. COHEN, M.I.T. Prof. H. C. Hottel, 218 pp. Photostats and microfilm available from M.I.T.'s Hayden Library. (June, 1955.)

The Effect of Particle Size Concentration and Temperature on Heat Transfer to Clouds of Small Particles. C. M. OKTAY, University of Florida. Prof. W. F. Brown, 144 pp. Photostats 25 cts./page plus $1.00; microfilm $5.76, available from university library. (January, 1955.)

Heat Transfer and Fluid Dynamics in Mercury-Water Spray Columns. ROBERT D. PIERCE, University of Michigan. Prof. J. J. Martin. 186 pp. Positive microfilm 0.01¼ cts./page. Abstract published in Microfilm Abstracts. (1955.)

Heat Transfer to Fluidized Beds. ISIDRO CALDAS, University of Cincinnati. Prof. Robert Lemlich, 110 pp. Copies available for loan from university library. (August, 1955.)

Heat Transfer for Flow over a Flat Plate with Blowing, Acceleration, and Non-Uniform Wall Temperature.* RANE L. CURL, M.I.T. Prof. H. S. Mickley, 236 pp. Photostats and microfilm available from M.I.T.'s Hayden Library. (February, 1955.)

Heat Transfer to Granular Beds from Vibrating Plates. DAVID STEPHAN, Ohio State University. Prof. Webster B. Kay, 187 pp. One copy available for loan from school library. (June, 1955.)

Heat Transfer and Solid Mixing in Fluidized Beds.* HENRY D. GIROUARD, M.I.T. Profs. W. K. Lewis and E. R. Gilliland, 275 pp. Photostats and microfilm available from M.I.T.'s Hayden Library. (September, 1954.)

Radial Heat Transfer in Fixed Beds. SHOU SOON KWONG, Purdue University. Prof. J. M. Smith, 129 pp. Copies available for loan from school library or Chemical Engineering Department. Photostats 20 cts./page; microfilm 0.07½ cts./page for first 100 frames (a frame is about 2 pages). (August, 1955.)

Simultaneous Heat and Mass Transfer in Natural Convection.* WILSON G. MATHERS, University of Minnesota. Profs. Edgar L. Piret and Arthur J. Madden. One copy available for loan from university library. (February, 1955.)

A Study of Heat Transfer to Liquid-Solid Suspensions Flowing Turbulently in a Horizontal Pipe.* CHARLES M. WHITE, Georgia Institute of Technology. Prof. J. M. DallaValle, 85 + xi pp. Copies for loan available from school library. (July, 1955.)

A Study of the Thermal and Physical Properties and Heat Transfer Coefficients of Sulfate Paper Mill Black Liquor. R. L. HARVIN, University of Florida. Prof. W. F. Brown, 146 pp. One copy available for loan from school library. Photostats 25 cts./page plus 1.00; microfilm $5.84. (January, 1955.)

ION EXCHANGE

Continuous Countercurrent Ion Exchange: Resin Particle Settling Rates and Mass Transfer in Spinner Columns.* JULIUS B. E. OLIN, University of Washington. Prof. Joseph L. McCarthy, 104 pp. One copy available for loan from school library. Microfilm .03 cts./page. (June, 1955.)

The Development and Characterization of an Ion Exchange Belt for Continuous Processes. BERT W. STRUTH, Polytechnic Institute of Brooklyn. Prof. Paul F. Bruins, 224 pp. Copy available for loan from school library. (June, 1955.)

KINETICS

Chemical Processing at High Temperature and High Pressure.* PAUL A. LOBO, University of Michigan. Prof. C. M. Sliepcevich, 103 pp. One copy available for loan from school library. Positive microfilm 0.01¼ cts./page. Abstract and conclusion published in Microfilm Abstracts. (1955.)

Continuous Countercurrent Liquid-Gas Reactor Design.* JAMES P. HARVEY, West Virginia University. Prof. H. P. Simons, 106 pp. Two copies available for loan from school library. (1954.)

Decomposition of Hydrogen Peroxide Vapor.* THEODORE W. STEIN, M.I.T. Prof. C. N. Satterfield, 188 pp. Photostats and microfilm available from M.I.T.'s Hayden Library. (February, 1955.)

Equilibria in Esterification Systems.* MERLAN M. LAMBERT, West Virginia University. Prof. H. P. Simons, 120 pp. Two copies available for loan from school library. (1955.)

Effect of Operating Variables on Hydrogenation of Cottonseed Oil. IBRAHIM A. ELDIB, University of Oklahoma. Prof. Lyle F. Albright, (viii) 104 pp. One copy available for loan from school library. Microfilm 0.01¼ cts./page. (August, 1955.)

Ion Exchange as a Vapor Phase Catalyst.* ARTHUR J. HERRMAN, University of Washington. Prof. L. N. Johnson, 121 pp. One copy for loan from school library. Microfilm .03 cts./page. (February, 1955.)

The Kinetics of Mixed Acid Nitration of Toluene.* HENRY M. BRENNECKE, University of Texas. Prof. K. A. Kobe, 101 pp. Copies available on loan from university library. (August, 1954.)

Kinetics of the Pyrolysis of Oil Shale in a Fluidized Solids System. LEO DI RICCO, University of Colorado. Prof. Paul L. Barrick, 66 pp. Microfilm available from University Microfilms. (May, 1955.)

Liquid-Phase Turbulent Mixing Properties.* JOHN M. PRAUSNITZ, Princeton University. Prof. R. H. Wilhelm, 106 pp. Microfilm available from University Microfilms, Ann Arbor, Mich., 4 cts. a frame (a frame is about 2 pages). August, 1955.)

The Rate of Nitration of Benzene with Mixed Acid. ROBERT D. BIGGS, University of Michigan. Prof. R. R. White, 94 pp. One copy available on loan from school library. Positive microfilm 0.01¼ cts./page. Abstract and conclusion published in Microfilm Abstracts. (1955.)

Rates of Condensation of Acetone to Mesityl Oxide in Cation Exchange Resins.* FRANK G. KLEIN, University of Michigan. Prof. J. T. Banchero, 131 pp. One copy available for loan from library of school. Positive microfilm 0.01¼ cts./page. Abstract and conclusion published in Microfilm Abstracts. (1955.)

Toluene Nitration Kinetics.* ALLEN J. BARDUHN, University of Texas. Prof. K. A. Kobe, 197 pp. Copies available for loan from school library. (June, 1955.)

Vapor Phase Hydration of Butene-2 to Butanol-2.* CHARLES B. DALE, University of Michigan. Prof. C. M. Sliepcevich, 164 pp. One copy available for loan from school library. Positive microfilm 0.01¼ cts./page. Abstract and conclusion published in Microfilm Abstracts. (1955.)

MASS TRANSFER

Local Rates of Mass Transfer in a Packed Bed of Spheres with Orifice Entry of Air.* CHARLES M. THATCHER, University of Michigan. Prof. J. C. Brier, 220 pp. One copy available for loan from school library. Positive microfilm 0.01¼ cts./page. Abstract and conclusions published in Microfilm Abstracts. (1955.)

Mass Transfer in a Distillation Column.* JOHN E. ANDERSON, M.I.T. Prof. E. R. Gilliland, 259 pp. Photostats and microfilm available from M.I.T.'s Hayden Library. (February, 1955.)

Part I—Material Transfer in Turbulent Gas Streams—Influence of Shape on Evaporation of Drops of n-Heptane. Part II—Thermal and Material Transport from Spheres into a Turbulent Flowing Air Stream. Part III—Temperature Gradients in Turbulent Gas Streams, Recovery Factors in Steady Uniform Flow.* KAZUHIKO SATO, California Institute of Tech-

nology. Prof. B. H. Sage, 147 pp. One copy available for loan from school library. (1955.)

Molecular Diffusion and Interfacial Transfer in the Solid Copper-Liquid Lead System.* JOHN W. GERMAN, University of Minnesota. Prof. Geo. W. Preckshot, 112 pp. + 43 pp. appendices. Copies not available. (May, 1955.)

PHASE EQUILIBRIA

Equilibrium Studies of the System Na_2O-CO_2-H_2S-H_2O.* KLAUS L. MAI, University of Washington. Prof. A. L. Babb, 107 pp. Copies available for loan from school library. Microfilm .03 cts./page. (December, 1954.)

Equilibria-Temperature Data for the Water-Phenol-o-Cresol System. H. B. KENDALL, Case Institute of Technology. Prof. T. J. Walsh, 68 pp. One copy available on loan from school library. Microfilm $1.50. (June, 1955.)

Equilibrium Water Contents of Natural Gas Dehydrated by Aqueous Diethylene and Triethylene Glycol Solutions at Various Temperatures and Pressures. FRANCIS M. TOWNSEND, University of Oklahoma. Profs. R. L. Huntington and L. S. Reid, 118 pp. One copy abailable for loan from school library. Microfilm 0.01¼ cts./page. (August, 1955.)

RHEOLOGY

Flow Behavior of Neoprene Latex.* ARIE E. LEVY-PASCAL, Case Institute of Technology. Prof. Samuel H. Maron. Copies not available. (June, 1955.)

Flow Behavior of Low Temperature GR-S Latex.* SHIU-MING FOK, Case Institute of Technology. Prof. Samuel H. Maron. Copies not available. (June, 1955.)

THERMODYNAMICS

Diffusion of Methanol in Aqueous Solution. ALBERT P. EARLE, Princeton University. Prof. R. K. Toner, 101 pp. Microfilm available from University Microfilms at .04 cts./frame (a frame is usually 2 pages). (September, 1955.)

The Heat Capacity Over the Range 15-315° K, Heat of Fusion and Derived Thermodynamic Properties of Alpha-and-Beta-Pinene.* HENRY A. McGEE, JR., Georgia Institute of Technology. Prof. W. T. Ziegler, 127 pp. One copy available for loan from school library. Negative photostats 35 cts./page. Microfilm .06½ cts./page—minimum $1. (June, 1955.)

Heat of Mixing Liquids. HAROLD W. SCHNAIBLE, Purdue University. Prof. J. M. Smith, 131 pp. Copy for loan filed in school library. Microfilm 0.07½ cts./page for first 100 frames (a frame is usually 2 pages). (June, 1955.)

The Phase Behavior and Solubility Relations of the Benzene-Water System.* CHARLES REBERT, Ohio State University. Prof. Webster B. Kay, 95 pp. (August, 1955.)

Phase Equilibrium in Systems with Supercritical Carbon Dioxide.* R. A. SNEDEKER, Princeton University. Prof. J. C. Elgin, 71 pp. Copy available for loan from school library. Microfilm 0.04 cts./frame (a frame is usually 2 pages). September, 1955.)

Physical and Thermodynamic Properties of Trifluoromethane. YU-CHUN HOU, University of Michigan. Prof. J. J. Martin, 111 pp. One copy available for loan from school library. Positive microfilm 0.01¼ cts./page. Abstract and conclusion published in Microfilm Abstracts. (1955.)

The Pressure—Volume—Temperature Properties of Sulfur Dioxide.* LANGLEY R. HELLWIG, University of Texas. Prof. K. A. Kobe, 151 pp. Copies available for loan from school library. (June, 1955.)

Studies of Thermal Conductivity of Liquids.* BYRON C. SAKIADIS, Louisiana State University. Prof. Jesse Coates, 90 pp. One copy available for loan from school library. (June, 1955.)

The Thermodynamic Functions of the Chloroethanes. ROLAND H. HARRISON, University of Texas. Prof. K. A. Kobe, 101 pp. Copies for loan available from school library. (June, 1955.)

A Thermodynamic Study of the System Benzene-Pyridine-Water. ROBERT E. WAGNER, Princeton University. Prof. R. K. Toner, 169 pp. Copy available for loan from school library. Microfilm 0.04 cts./frame (a frame is usually 2 pages). (May, 1955.)

The Viscosity of Gas Mixture at Variable Pressure and Temperature.* WARREN W. CLAUSON, Illinois Institute of Technology. Prof. Ralph E. Peck, 44 pp. No copies available for loan. (June, 1955.)

VAPOR LIQUID EQUILIBRIA

Correlation of the Vaper Liquid Equilibrium Constants of Hydrocarbons (2 Vols.). DONALD F. HINSHAW, University of Michigan. Prof. George G. Brown, 358 pp. One copy available for loan from school library. Positive microfilm 0.01¼ cts./page. Abstract and conclusion published in Microfilm Abstracts. (1955.)

Liquid-Vapor Equilibria of the Systems Bromine Pentafluoride-Bromine Trifluoride. RAY D. LONG, University of Michigan. Prof. J. J. Martin, 120 pp. One copy available for loan from school library. Positive microfilm 0.01¼ cts./page. Abstract and conclusion published in Microfilm Abstracts. (1955.)

MISCELLANEOUS

Adhesion of a High Molecular Weight Polymer.* ROBERT M. LURIE, M.I.T. Prof. H. P. Meissner, 239 pp. Photostats and microfilm available from Hayden Library, M.I.T. (September, 1955.)

An Orthogonal Polynomial Equation of State—Part I. Application of the Benedict Equation of State to the Methane-n-Pentane System—Part II. Isobaric Heat Capacity at Bubble Point of n-Decane—Part III.* CORNELIUS J. PINGS, JR., California Institute of Technology. Prof. B. H. Sage, 189 pp. One copy available from Main Library. (1955.)

The Effect of Shear Rate on Solution Viscosity Methods. KENNETH H. CRAM, Princeton University. Prof. J. C. Whitwell, 193 pp. Copies available from University Microfilms, Ann Arbor, Mich. 4 cts. a frame (usually 2 pp.). (February, 1955.)

Electrical Charge Transfer in Adhesion.* JOSEPH GAYNOR, Case Institute of Technology. Prof. George W. Blum, Prof. Selby M. Skinner, 154 pp. One copy available from Case Library. No separate abstract.

Ion Distribution During Electrolysis. HERBERT DENGLER, Columbia University. Prof. H. Linford, 80 pp. Microfilm not available until May, 1957. Photostat 10 cts./page; microfilm 0.01¼ cts./page. (1954.)

Ion Exclusion Equilibria for Glycerol, Sodium Chloride, Water, and Dowex-50 with Application to Continuous Column Design.* EDWARD L. SHURTS, University of Michigan. Prof. R. R. White, 115 pp. Copies available for loan from school library. Positive microfilm 0.01¼ cts./page. Abstract and conclusions published in Microfilm Abstracts. (1955.)

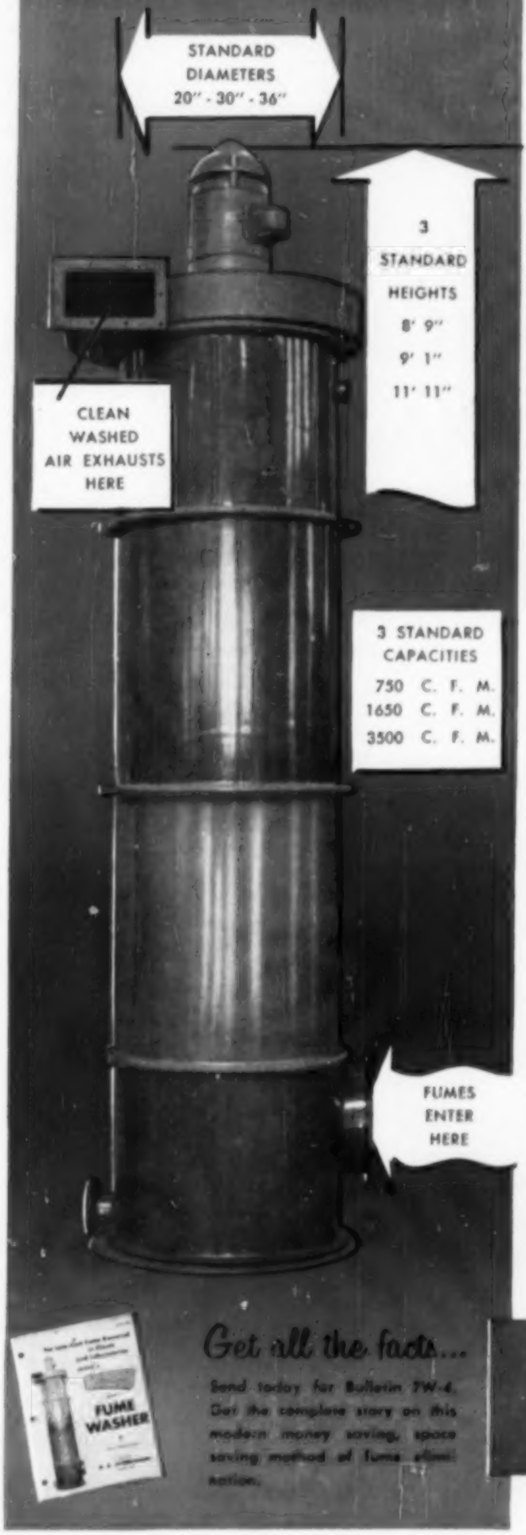
Reactions of Butadiene. JAMES L. HECHT, Yale University. Prof. B. F. Dodge, 217 pp. Copies available from school library. Abstract and conclusion available separately. (June, 1955).

Sedimentation of Compressible Sludges.* EDWARD T. GEORGE, Yale University. Prof. Charles A. Walker, 322 pp. Copies available on loan from school library. Abstract and conclusions available separately. (June, 1955.)

Studies in Continuous Reactor Design. Graphical Design of Continuous Stirred Tank Reactors. Control of Continuous Stirred Tank Reactors.* OLEGH BILOUS, University of Minnesota. Prof. Edgar L. Piret. One copy available for loan from school library. (November, 1954.)

The Utilization and Mechanical Separation of Sugarcane Bagasse.* ROBERT M. HANSEN, Louisiana State University. Prof. Arthur G. Keller, 192 pp. One copy available from the university. Photostat $38.50; microfilm $5.76. (June, 1955.)

NOW, CORROSIVE FUMES EFFICIENTLY REMOVED BY NEW LOW COST



Cyclonaire

PORTABLE

FUME WASHER

Absorbs noxious and corrosive fumes
Removes irritating and abrasive dusts
Supresses oil and acid mists

The Cyclonaire is surprisingly compact—will fit almost anywhere, but it does a big fume removal job formerly possible only with expensive custom-designed units. It will safely handle corrosives in low concentrations normally encountered in fume scrubbing operations. Removal of many gases (of 1% concentration or less)—is up to 99.9% effective. Low power requirements make it very economical to operate.

In operation the Cyclonaire is a wet bed scrubber—with an all important difference. Instead of designing the unit first, then selecting a packing . . . our engineers designed the unit around Intalox saddle packing, the most efficient industrial tower packing made. The results surprised even us. We discovered that it is possible to do a big fume removal job with a small fume washer . . . when packed with Intalox!

The Cyclonaire is constructed of steel in easy-to-assemble flanged sections, secured by split ring clamps (the 36" size is bolted). All inner and outer surfaces are protected by an inert Tygon or Tygoflex plastic coating. It can be assembled in a few hours, or disassembled and reinstalled in a different location in an equally short time.

The Cyclonaire is available in three standard sizes and three capacities. (See illustration.) It is shipped as a "package" unit complete with motor and adequate Intalox packing. Special parts are available to convert standard units for unusual applications.

If you have a fume, dust or mist problem it will pay you to look into the low cost . . . pint sized . . . high efficiency Cyclonaire.

PROCESS EQUIPMENT DIVISION
U. S. STONEWARE
AKRON 9, OHIO

135E

STAINLESS BRANCHES OUT

New types of stainless steel are on the market, more being developed, as steel makers look ahead.

With the temporary nickel shortage seeming to be a chronic situation, and demands of process equipment fabricators continually calling for new alloys to fit their needs, the steel companies are digging more and more into new varieties of stainless steel.

For some time now Allegheny Ludlum has been working on stainless types made with manganese replacing much of the usual nickel. During the Korean War one such alloy, the 15-15-1 type (15% chromium, 15% manganese, 1% nickel), was widely used. The small nickel content was dictated by Government restrictions on nickel, and while the corrosion resistance of the alloy was about equal to the straight chromium grade Type 403, it was slightly inferior to chrome nickel grades normally used in process equipment fabrication.

Now Allegheny has two other alloys of low nickel content. One, with a nominal composition of 17% chromium, 6% manganese, and 4% nickel, has the desirable high strength and corrosion resistance, the good formability and easy weldability of the highly popular 17 chromium-7 nickel Type 301 so familiar to fabricators. Assigned AISI Type 201, the 17-6-4 alloy is resistant to atmospheric and most other corrosive conditions where Type 301 is usually applied, and few changes in fabrication methods or tools are required.

The second new alloy from Allegheny is the 18% chromium, 8% manganese, and 5% nickel, named Type 202. This is an alternate for Type 302, mechanical properties and corrosion resistance are similar to that material.

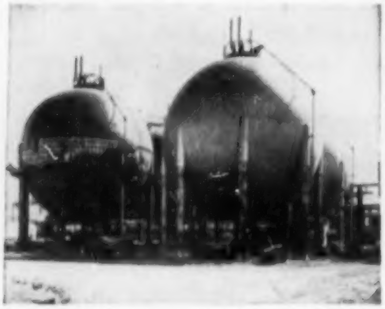
All of these new stainless alloys are now available in sheet and strip, will probably be marketed in other products soon, particularly the Type 202.

Of course, these new stainless types did not grow without headaches, have certain marked differences from the normal nickel types. Manganese content tends to reduce resistance to oxidation at elevated temperatures, and Type 202 is not recommended for applications at temperatures above about 1500° F. in oxidizing atmospheres. The new types are somewhat stronger in the annealed state but work harden about the same as similar higher nickel types.

U. S. Steel, also working on new types of stainless with less nickel content, has found that by careful adjustment of the chemical composition of the steels, particularly the chromium and manganese content, sound ingots can be made with much higher nitrogen content than heretofore thought possible. This, according to U. S., opens the door to an entirely unexplored area for the reduction of nickel content. While admitting that there are many kinks still to be ironed out in both the production of low-nickel alloy steels, and in their fabrication use, U. S. feels that a whole new field may be opened up, not merely the creation of substitutes for nickel-steels.

Certainly the chrome-manganese family is far from complete. In particular much work remains to be done in the area of high temperature stainless types. But work is progressing at a rapid pace, and fabricators can expect to have many new low-nickel types to work with in the future production of process equipment.

Increased production of its line of fine chemicals will be a major result of Chemo Puro Manufacturing Corp.'s move to a new plant site in Newark, N. J. One reason for picking the pictured Newark site is the company's planned entry into petrochemicals, raw material to come from Texas by water. □



Pittsburgh Corning's "Foamglas" is the secret of low-temperature maintenance on these 55-ft. diameter anhydrous ammonia spheres of U. S. I. Division of National Distillers. Through refrigeration and the insulating properties of the Foamglas, the anhydrous ammonia is kept at a pressure of 55 lb./sq.in. at 26° F., despite constant exposure to the sun. □

LIQUID METAL REACTOR A COMMERCIAL POSSIBILITY

Industrial group working on the potential of liquid metal as a reactor fuel reports feasibility, possible economic attractiveness, technical kinks still to be ironed out.

Various types of nuclear reactors are being studied for commercial application. Now a group of 14 industrial, and 3 non-industrial, organizations has reported on the possibilities of the liquid fuel concept. Result: Liquid metal is believed to be technically feasible in the near future, gives promise of being economically attractive.

The group,* organized and administered by Babcock & Wilcox, based its study on the pioneering work of Brookhaven National Laboratory, estimates that a full-scale plant with an electrical capacity of 226,000 KW could be built and operated for .071 cents per KWH, a cost lower than that of high-cost conventional fuel plants. If four such reactors were built in one area the cost would come down to .065 cents since initial and operating costs do not go up in direct proportion to added capacity.

Economic-Technical Study

The work of the fifty scientists and engineers engaged in the study was actually an exploration of the economic and technical feasibility of the LMFR system developed at Brookhaven. In essence what they found was that the LMFR has distinct technical and economic advantages, equally distinct problems to be solved.

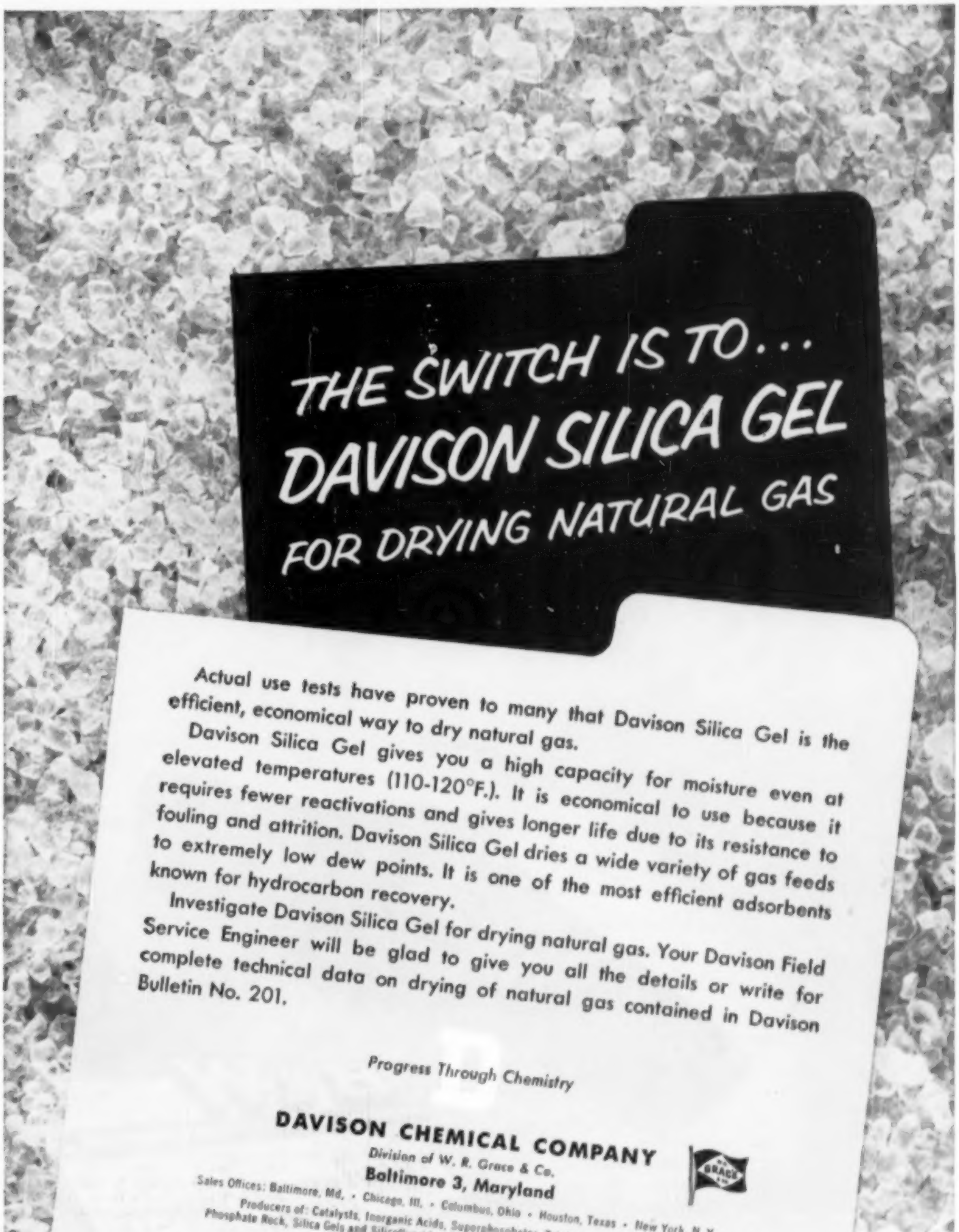
The system is capable of generating electric power, producing new fuel for itself, and delivering by-products to waste tanks, all in a continuous process. It is flexible, can function as a regenerative or non-regenerative reactor over a wide range of outputs. It will employ complete, continuous chemical processing of both core and blanket materials on the site and can be connected to the most modern turbines.

These are some of the advantages claimed by the group involved in liquid metal reactor study.

---

* Air Reduction, American Gas & Electric (member, Nuclear Power Group), American Smelting & Refining, Bailey Meter Co., Bechtel Corp. (member, Nuclear Power Group), Carbide & Carbon Chemicals, Detroit Edison Co. (representing Atomic Power Developments Associates), Dow Chemical, Ethyl Corp., International Nickel Co., Inc., Merck & Co., National Carbon, AEC's Oak Ridge National Laboratory, Rensselaer Polytechnic Inst., Tennessee Valley Authority, and Vanadium Corp. of America, in addition to Babcock & Wilcox.

(*Continued on page* 38)


THE SWITCH IS TO...
DAVISON SILICA GEL
FOR DRYING NATURAL GAS
Actual use tests have proven to many that Davison Silica Gel is the efficient, economical way to dry natural gas.
Davison Silica Gel gives you a high capacity for moisture even at elevated temperatures (110-120°F.). It is economical to use because it requires fewer reactivations and gives longer life due to its resistance to fouling and attrition. Davison Silica Gel dries a wide variety of gas feeds to extremely low dew points. It is one of the most efficient adsorbents known for hydrocarbon recovery.
Investigate Davison Silica Gel for drying natural gas. Your Davison Field Service Engineer will be glad to give you all the details or write for complete technical data on drying of natural gas contained in Davison Bulletin No. 201.
Progress Through Chemistry
DAVISON CHEMICAL COMPANY
Division of W. R. Grace & Co.
Baltimore 3, Maryland
Sales Offices: Baltimore, Md. • Chicago, Ill. • Columbus, Ohio • Houston, Texas • New York, N. Y.
Producers of: Catalysts, Inorganic Acids, Superphosphates, Triple Superphosphates, Phosphate Rock, Silica Gels and Silicofluorides. Sole producers of DAVCO® Granulated Fertilizers.

THE Case OF THE RECALCITRANT TUBE

FACTS: High pressure, high temperature refinery application (hydrogenation of petroleum)
Tubing in question was stainless type 347
Tubing met original specification for job

CLUES: Tubing was in service for about 100 hours at a pressure of 10,000 psi and a temperature of 1100 F, before failure.

EXAMINATION REVEALED: Temperatures and/or pressures used in actual testing or operation exceeded the original specifications
Failure resulted from progressive wall thinning due to creep

POSSIBLE SOLUTIONS: Change operating conditions
Use a thicker wall tube. Change tube material

B&W SUGGESTION: When it comes to choosing a tube, consider *every* factor involved, including possibility of exceeding current service conditions. *And* get the benefits of Mr. Tubes' long experience with tubing for every kind of application. He knows his tubes—what they will and what they won't do. Call him in at any time. He's as close as the phone at your elbow.

TA-5066 P

THE BABCOCK & WILCOX COMPANY
TUBULAR PRODUCTS DIVISION, BEAVER FALLS, PA.

Seamless and Welded Tubular Products, Seamless Welding Fittings and Flanges—in Carbon, Alloy and Stainless Steels

Here's Why It Pays To Start With

"Karbate" Impervious Graphite Process Equipment — And Contnues To Pay While You Use It:

Low First Cost: Prices of standard, quantity-produced "Karbate" Process Equipment compare favorably with those of other materials less resistant to corrosion. Delivery is quick — generally from stock.

Long Service Life: Unequalled corrosion-resistance, immunity to thermal shock and ruggedness of mechanical design keep "Karbate" Process Equipment on the job with minimum maintenance.

No other material of construction combines the advantages listed above with such other desirable properties as high thermal conductivity, freedom from metallic contamination, ease of fabrication and modification in the field, plus a *complete technical advisory service.* Literature furnished promptly on request.

Manufactured only by

NATIONAL CARBON COMPANY

The term "Karbate" is a registered trade-mark of Union Carbide and Carbon Corporation

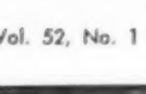
NATIONAL CARBON COMPANY

A Division of Union Carbide and Carbon Corporation

30 East 42nd Street, New York 17, New York

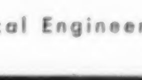
Sales Offices: Atlanta, Chicago, Dallas, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco

IN CANADA: Union Carbide Canada Limited, Toronto



Pumps— Catalog Section S-7250

Pipe and Fittings — Catalog Section S-7000



Heat Exchangers— Catalog Sections S-6740 and S-6840

Cascade Coolers— Catalog Section S-8820

HCl Absorbers — Catalog Section S-7460

INDUSTRIAL NEWS

LIQUID METAL REACTOR

(Continued from page 34)

On the other hand, the group admits there are many technical problems to be solved before the potential of the liquid fuel reactor can be realized commercially.

Problems

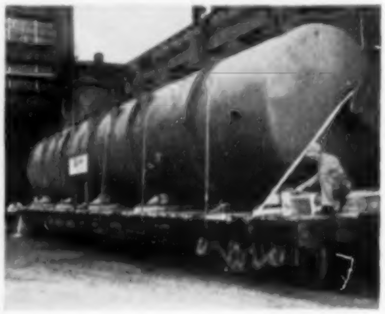
Companies engaged in work with solid fuel reactors, such as Sylvania, point to certain of these problems. Corrosion seems to be a serious hurdle, so serious that the solid reactor people admit that once it is hurdled the liquid reactor will be a strong factor in the nuclear field.

Other technical difficulties pointed to by solid reactor men are the need for a completely leak-proof system, the need for high-pressure operation in some cases, "mass-transfer" resulting in the plugging of heat exchanger coils, and the high construction and maintenance costs resulting from these considerations.

Room For All

Solid fuels seem to have the lead at present, but liquid fuel backers are hard at work solving their problems, have already solved many. The real picture seems to be that, like coal, oil and gas, there is room for all types of reactors, each has its problems, its advantages, its special applications, and its potential. It would certainly seem that Sylvania is probably right when it asserts that no single type of reactor is likely to prove best in all situations.

The problem now is for the engineers to make all types workable, commercial, and economically useful.



One of the largest pieces of equipment ever made by the Biggs Boiler Works, Akron, is being shipped to Firestone's Lake Charles, La., synthetic rubber plant. The column, 50 ft. long with a 9-ft. diameter, is a styrene stripping column for recovering excess styrene. □

Corrosioneering News

Quick facts about the services and equipment Pfaudler offers to help you reduce corrosion and processing cost.

Published by The Pfaudler Co., Rochester, N.Y.

What Progress Against Corrosion in 1955?

A top-level report by DONALD A. GAUDION

Vice-President, The Pfaudler Co.

How big a problem is corrosion?

Some sources tell me it costs industry about six billion dollars a year. In petroleum alone, every barrel of crude oil processed eats up 9¢ worth of equipment.

And with today's trends toward higher pressures, higher temperatures, continuous processes, you can expect corrosion to step up its attack on your equipment.

At Pfaudler, we traffic in corrosion-resistant equipment. Our specialty is a material called "glassed steel"—acid-alkali-resistant glass, permanently fused to steel, to give you the corrosion resistance of glass plus the structural strength of steel.

At the same time we have developed a broad knowledge of corrosion-resistant alloys, like Hastelloy, inconel, monel; the stainless steels; aluminum; copper; titanium; and synthetics, such as Teflon and Kel-F.

Guarantee against corrosion

Several innovations appeared, to help you lick corrosion. A hitherto unheard of guarantee was given: No corrosive destruction for 12 months on Pfaudler glassed steel equipment!

We also introduced a new glassed steel dryer-blender . . . Bigger reactors in money-saving *standard* designs . . . New nonmetallic seals for agitators on reaction kettles . . . New glass Turbogrid column trays . . . and other new or improved units.

While our research crew probed the future, we also added greatly to our knowledge of corrosioneering by examining reports from users of Pfaudler equipment over the past year. For example, we learned that, in 28 installations, our "packaged" system for plating acid recovery usually paid for itself in 6 to 12 months.

More engineering services

To further help you with corrosion problems, we revamped our technical staff, adding a new Applications Engineering Group. You can add their experience to yours whenever you are faced with special projects. They can "take over" if you want them to.

Corrosion Seminars

To increase general knowledge of new developments, we conducted four Corrosion Seminars during the year. Also, technical talks and articles were delivered by Pfaudler people. In research, we have continued our scholarships at Ohio State, Rochester, and Penn State Universities, Rochester Institute of Technology and Rensselaer Polytechnic Institute.

To you, who must pay the bill for corrosion, we believe these progressive steps are significant and worthy of your investigation. Meantime, we are searching daily for new approaches, and will report frequently to you on the pages of this publication.

A comprehensive report on the new equipment mentioned by Mr. Gaudion is available, and will be sent to you on request.

Los Angeles Meeting Program . . .

Monday, February 27

A, B, C's OF MACHINE COMPUTATION, R. Curtis Johnson, Washington University, presiding.

Symposium will be essentially educational in nature, designed for those with little or no present knowledge of the field.

Introduction to Digital Computers, C. B. Tompkins & F. H. Hollander, Numerical Analysis Research, UCLA.

Logical set-up of a digital computer is explained by comparing it to a human being. Memory units, input-output equipment are discussed. Costs are analyzed, the entire economics of the digital machines is discussed.

The General Purpose Electronic Differential Analyzer, T. J. Williams & C. L. Johnson, USAF Inst. of Tech., Dayton, O.

The strong points and drawbacks of the general purpose analog computer, with specific reference to its application to the analysis of chemical processes.

The Small Computer Installation, A. Opler, Dow, Pittsburg, Calif.

Experience on the part of chemical engineers with the mechanized or electronic versions of simple addition and multiplication machines developed used for accounting, form a base for easy transition to the larger machines.

The Larger Computer Installation, A. E. Hoerl, Du Pont, Wilmington, Del.

The basic factors, including economics, manpower needs, program demand, etc., concerning the large installations are discussed.

Training of Engineers For Use Of Computers, T. J. Walsh, Case Inst., Cleveland, O.

How to train engineers for setting up problems in a form to be solved by the large, seemingly complicated new machines.

THE STUDY AND CONTROL OF FAST REACTIONS, W. H. Corcoran, presiding.

A symposium devoted to the fundamentals and technology of the freezing of chemical equilibria.

A Ballistic Piston for the Investigation of Gas Phase Reactions, P. A. Longwell & B. H. Sage, Cal. Tech, Pasadena.

A method for determining the kinetics of the gas phase reactions at high temperatures and pressures, particularly of some little-understood systems of special industrial interest.

Relaxation Times for Fast Reactions from Phase Lag Measurements, S. H. Bauer, Cornell Univ.

The most sensitive feature characterizing a periodic process (given the frequency) is its phase. The pros and cons of a little-used method for measuring phase-lag are discussed, typical data for vibration-translation relaxation presented.

Heat Conductivity in Chemically Reacting Gases, J. O. Hirschfelder & C. F. Curtiss, Univ. of Wisconsin.

The relation of reaction rates, composition, heat flux, and other factors when a chemically reacting gas mixture is confined experimentally between parallel plates, one hot and the other cold.

Wisconsin Process Furnace for Nitrogen Fixation, E. D. Ermenc, Food Machinery and Chemical, New York.

Description with process data of new method for direct nitrogen fixation using a heated pebble furnace, based on successful operation of a pilot-scale plant.

The Practical Application of Fast Reactions In The Field Of Combustion, E. H. Seymour, Thermal Research and Eng'g, Conshohocken, Pa.

Presenting some of the problems in the practical application of fast reactions, particularly a major application, combustion.

(Continued on page 46)

Chemical Center of Western U. S. Scene of Next Institute Meeting

By F. G. Sawyer
Ralph M. Parsons Co.

"Growing like an asparagus stalk after an April shower" was the phrase used to describe the Los Angeles basin in 1887. . . .

That this prediction is still accurate, especially as far as the chemical process industries are concerned, will be witnessed by Institute members and guests attending the forthcoming National A.I.Ch.E. meeting, Feb. 26-29.

A center of chemical processing plant location, Los Angeles and environs literally abounds with qualities making it a region of unusual interest to visiting chemical engineers. That some of these qualities arise from a strange mixture of great natural abundance (climate, minerals, etc.) together with almost equally great shortages (fresh water and air, etc.) only make the vigor of the Los Angeles technologist more pronounced.

As a cultural center, Los Angeles reflects the early interest of generations who wanted the west coast to have educational facilities comparable to those anywhere. With such a beginning, wartime impetus to aircraft, atomic, and a host of other scientific and industrial activities has brought about a concentration of engineers and scientists specializing in computing techniques, instrumentation, and other activities presently of great interest to chemical engineers. The more recent onset of climatic and fresh-water problems has brought to the region unquestionably the leading staffs of workers who are confidently tackling some of the grandest projects of man since the building of the pyramids—the protection of an atmosphere from contamination, and the desalting of a sea!

ON THE SOCIAL SIDE

Sunday, 5:30 P.M.: Cocktail party.
Tuesday, noon: Luncheon.

As a vacationland, Los Angeles will provide in late February a climate which should be roughly comparable to late spring in most sections of the country—except, that Los Angeles will be geared to outdoor activities on a summer-scale. Swimming will be pleasant—in heated pools, which are commonplace. Temperatures will range around 65°, and one can expect fair weather with sunny days followed by cool (topcoat) nights. The highly heralded flora of Southern California will be in full bloom, with the Bougainvillea and desert flowers displaying their colors and scents against a palm-tree background.

Southern California as a vacationland is so thoroughly stocked with interesting things to see and places to go, that the chemical engineer will find his experience not only pleasant, but tremendously broadening. For this reason, the taking of a few days vacation before, after, or both, while in the area, will be extremely rewarding. The same can be said for the careful planner who, taking advantage of airline or railway family-plan reduced rates, will make it possible for his wife to enjoy a winter vacation at very little extra cost.

Truly one of the greatest attractions about the Los Angeles area is the tremendous variety of scenery offered with-

(*Continued on page* 44)

Los Angeles' Statler Hotel, scene of the meeting

in easy driving distance. With the practicality of the drive-yourself rental car, hardly anyone should miss those scenic spots, missions, observatories, beaches, studios, or any other of the multitude of attractions within such easy reach.

Skiing, hiking, photography, astronomy, motoring . . . whatever one's hobbies, there will be plenty of opportunities to carry them out, and probably other chemical engineers interested in joining to make up a group. The aid of local committee people can be depended upon, for guidance as to arrangements, advice on facilities, etc.

For those interested in what the city has to offer, there will be the night clubs, TV studios, Hollywood, the Rose and Hollywood Bowls, the symphony, and so on.

Devotees of rod and reel are in paradise in Southern California. There will be deep sea fishing, surf fishing (trust the Californians to bring the best here if they haven't got it—striped bass brought west and stocked in the sea!), and fresh water fishing up in the mountains.

For those more interested in the serious side a visit to UCLA, USC, or Cal. Tech may be just the thing. Then there is Griffith Park Planetarium, or the Museum of History, Science and Art. Not to be missed is a walk down Olvera street with its atmosphere of Mexico, new and old.

The Industrial Background

El Pueblo de Nuestra Senora la Reina de Los Angeles was founded in its still-magnificent valley in 1781. It remained a beautiful if sleepy village until the first carload of oranges went East by the newly completed transcontinental railroad in 1877, via its then big-brother, San Francisco. By 1880 the tourists, health seekers and people seeking a good place to live began their booming influx.

They discovered oil in 1892, the Panama Canal opened to make ocean shipments between the east economical, and soon after, Los Angeles was on its way to industrial importance. (Los Angeles County is still a leading oil producing area.) The motion picture people came next because they had found the climate unusually well suited for outdoor filming, and then World War II brought the industrial boom still in progress.

1955 CHEMICAL PLANT BOX SCORE

During 1955 alone, Allied built a new sulfuric plant at El Segundo. Borden completed a polyvinyl acetate plant at its Dominguez installation: initial production, 3,000,000 pounds a year. Under construction at Torrance is Carbide and Carbon's new polyethylene and ethylene glycol plant costing $36 million. Still at Torrance, Dow is building a styrofoam plant. Johns-Manville entry is a synthetic silica plant coming on stream at Lompoc. Finished in 1955 was Monsanto's phosphoric acid and detergent phosphates plant at Long Beach. Shell put in the works for 1956 a urea plant to be built at Ventura, capacity: 100 tons/day. Stauffer completed a 500-ton/day superphosphate and ammonium phosphate plant at Vernon; American Potash and Chemical is expanding sodium sulfate production by 20% at its Trona works. Brea chemicals put its 50,000 ton/year ammonium nitrate plant on stream in September, and North American Aviation completed a $1 million nuclear research laboratory at Downey. Union's new refinery at Santa Maria will make coke, gasoline stocks, gas oil, and sulfur—the sulfur capacity is now being doubled to 84 tons/day.

Between City Hall and the Sea: The Chemical Area

Until about 1915, Wilmington was a small fishing village. Then Pacific Coast Borax moved in, among other reasons to make use of the port's excellent potentialities. With the discovery of oil in the early 20's, the refineries chose the harbor area for their sites, to be followed by petrochemical and by-product developments. These offered attractive raw material sources for outright chemical manufacturers, who as is the custom, located their plants nearby. Thus has developed a concentration of refining, petrochemical, organic synthesis, and inorganic manufacturing plants which will be of great interest to the visiting chemical engineer.

At Torrance alone there's the Dow polystyrene plant, Carbide and Carbon's ethylene and polyethylene plant, Pittsburgh Plate Glass Co.'s alkyd resins unit, Shell Chemical's petrochemical installation, and others too numerous to mention. Wilmington, a hop, skip and jump from Torrance, has plants ranging from glycerin (Procter & Gamble) to gypsum (Kaiser Gypsum Co.). Neighboring Compton boasts, among other plants, Monsanto's polystyrene unit, and Arrowhead Rubber's silicone rubber plant. Borden's resins and emulsions plant is down the road at Dominguez, along with a major plant of Stauffer, Johns-Manville's asbestos factory, and so on.

It all adds up to one of the major chemical centers of the country—but all is not on the rosy side. Los Angeles chemical plants have met and overcome some of the most difficult waste product problems in the country (Richfield alone spent $6.7 million on air pollution control at one refinery). How the companies did it, are continuing to do it, is a big story for engineers with problems of their own.

Technical Program

The program arranged for the Los Angeles meeting promises to be one of the truly outstanding ones of the year. Economics, a subject which is always of great interest, is considered from the standpoint of management, the project engineer's and the designer's points of interest. The theme "how to decide" will be underlying, and such aspects as "when to abandon" will be given thorough analysis.

Three other symposia of wide general interest should be given careful consideration by the chemical engineer contemplating attending the Los Angeles meeting. These have to do with professional personnel, control over atmospheric contamination, and a "how to" session on adapting oneself to the use of the large and small computing machines now at the disposal, either directly or through temporary "time charge" arrangements, of many members of the profession.

(*Continued on page 46*)

The "Precious Plus" that didn't appear on the Blueprints
You *see* reactors, vessels, towers and piping — and they have the familiar look of any other Paraxylene and Udex plant. But what you *don't see* — what blueprints cannot show — is the "Precious Plus" that earmarks this "a BMC project".
At the time BMC was awarded the design and construction contract, the client had *firm* commitments to ship paraxylene within a fixed time period . . . a time period that would require tight scheduling — even for *conventional* design and construction.
But there was nothing ordinary about *this* Paraxylene plant. It called for a unique crystallizing process — developed by BMC but never before used — that would require time-consuming creative engineering.
Working under almost prohibitive time pressures, a BMC Task Force — with the *Key Man*+ in charge — tackled the job. There was no waste motion in engineering. Drafting geared itself to a back-breaking schedule. Equipment orders were placed early. Usual "bugs" were anticipated — and avoided.
The plant went "on-stream" ahead of the client's *fixed* schedule . . . and first shipments were on their way well in advance of the contract commitments. Cost? . . Substantially below the estimate despite the emphasis on speed.
You can't see it . . . you pay nothing for it . . . but the "Precious Plus" included in this project is a part of every BMC proposal. Many leading petroleum and petrochemical companies have found it a distinct advantage in getting better plants, faster and at a lower cost. How else explain the unusual growth BMC is enjoying?
+ BMC's *Key Man* operation is unique among major contract engineering firms. The BMC man who submits your proposal is *always* a BMC principal . . . *always* the Key Man heading up the Task Force responsible for the execution of your job. Clients tell us "This is the BMC difference that makes the difference."
The Udex and Paraxylene Plants described here were designed and constructed for Sinclair Refining Company, Marcus Hook, Pa.
BMC
BADGER MANUFACTURING COMPANY
230 Bent Street, Cambridge 41, Mass.
60 East 42nd Street, New York 17, New York
ENGINEERS · CONTRACTORS · DESIGNERS · MANUFACTURERS

LOS ANGELES (*Cont.*)

The only truly fundamental symposium, that on study and control of fast reactions, promises to greatly stimulate one's interest in and understanding of the mechanism of the reactions so many chemical engineers live with every day of their professional lives. To emphasize the practical application of some of these concepts, one paper will have to do with combustion in the ordinary use of the term. It will be shown how the burning of conventional fuels can be affected by attention to the "fast reaction" aspect of the oxidation reaction.

Plant Trips

A mixture of industrial and recreational factors will be included in the plant trips program, outlined in the general technical program section of this article. Besides visiting industrial plants, visiting chemical engineers will inspect CBS Television City, one of the outstanding installations in the country—staffed, as one can imagine, with Hollywood glamor!

For the Wives

Little need be said about the attraction the Southern California area has for the ladies. In the very heart of glamor-land, Los Angeles will offer a program for its lady guests second to none. To get each day off to a good start, morning coffee will be served each day by the host staff. Formal tours will take the ladies to Marineland and Huntington Gallery.

Los Angeles Meeting Program... (cont.)

Tuesday, February 28

TECHNIQUES OF ECONOMIC JUSTIFICATION FOR PROCESS INDUSTRY PROJECTS, Henry E. Wessel, presiding.

A symposium on how to decide whether to build, replace, or abandon a processing facility, including techniques for analysis and control of budgets.

The "Appropriation Request": Important Instrument For Control Of Capital Changes, H. R. Wager, Arabian-American Oil Co., New York.

"Appropriations requests" are advocated as a formal presentation medium having the advantage of being systematic, and assuring proper communication.

Comparison of Alternatives By Capitalized Cost, F. C. Jelen, Solvay Process Div., Syracuse, N. Y.

"Capitalized cost" is offered as a simple and exact method for comparing costs of engineering alternatives on a common denominator basis.

The Importance of Complete and Accurate Capital Cost Estimates in Economic Evaluations, J. Tielrooy, Brea Chemicals, Brea, Calif.

The factors to be considered in arriving at estimates of total plant cost, and the importance of "complete and accurate" capital cost estimates.

Interest Rate of Return for Capital Expenditure Evaluation, J. B. Weaver and R. J. Reilly, Atlas Powder, Wilmington.

The normal way of calculating "return on investment" may be misleading. A new method, "interest rate of return" will be shown to be more useful for the engineer evaluating capital expenditure.

Criteria For Discontinuing Operating Investments, N. W. Krase, DuPont, Wilmington, Del.

Knowing when to discontinue is an important part of process economics. A method for establishing a single index number offers a practical guide for decision.

SUPERVISION OF ENGINEERING AND SCIENTIFIC PERSONNEL (Panel Discussion), L. K. Cheney, chmn., R. D. Gray, Cal. Tech, Moderator. Panel Members: R. W. Krebs, Esso Standard, Baton Rouge, La.; T. R. Sandberg, Cutter Lab., Berkeley, Calif.; L. T. Lanz, Monsanto, St. Louis, Mo.; W. S. Martin, Procter & Gamble, Cincinnati, O.; A. L. Lyman, California Research, San Francisco.

A vital element in the success of any organization is the effectiveness of the supervision of engineering and scientific personnel. As a point of departure, the panel will develop a summary of the general characteristics of professional employees that make it necessary to have special and distinctive supervisory techniques, will debate the specific problems from there.

Wednesday, February 29

GENERAL PAPERS, Lee Van Horn, Fluor Corp., presiding.

Heat Transfer to Non-Newtonian Fluids, R. D. Vaughn, A. B. Metzner & G. L. Houghton, Univ. of Delaware, Newark, Del.

The first theoretical analyses combined with an experimental study of the variables controlling heat transfer rates to non-Newtonian fluids in the streamline flow region.

Diffusion and Reaction in Viscous Flow Tubular Reactor, F. A. Cleland & R. H. Wilhelm, Princeton Univ.

Effect on point and integral average conversion of chemical reaction, coupled with radial diffusion and radial distribution of reaction times in such reactors.

New Application of Analytical Instruments to Automatic Control, H. J. Noebels, Beckman Instruments, Fullerton, Cal.

A review of specific applications of current process control instruments that sense those physical properties offering control possibilities.

CBS Television City, one of six scheduled plant trips.

Automatic Logging, M. D. Shriver, Panellit, Skokie, Illinois.

Typical applications of data collecting and tabulating systems are reviewed.

Ferric Ion Removal From Dilute Acidic Solutions by Fixed Bed Cation Exchange, B. W. Mar & M. M. David, Univ. of Washington.

The use of ion exchange in recovering iron contamination from industrial wastes.

AIR POLLUTION, H. P. Munger, presiding.

A symposium on Tools and Techniques for cleaning of effluent gases to minimize contamination of the air.

Chemical and Physical Particle Conductivity Factors in Electrical Precipitation, H. J. White, Research-Cottrell, Bound Brook, N. J.

Certain problems have arisen, through insulating factors, in the application of electrical precipitation techniques for cleaning gases.

Tracers and Air Pollution, F. G. Sawyer & W. H. Shallenberger, Ralph M. Parsons Co., Los Angeles, Cal.

Use of fluorescent tracer materials to determine paths of air-borne pollutants is a valuable and practical tool.

Adsorption and Absorption of Toxic Vapors by Airborne Particles, V. A. Gordieyeff, Army Chemical Center, Md.

The mechanisms of interaction between airborne dusts, mists or fogs and toxic vapors, and the toxological significance of these interactions.

A Survey of New Engineering Tools and Techniques for Cleaner Air, O. C. Thompson, Carbide & Carbon, South Charleston, W. Va., and G. W. Blum, Goodyear, Akron, O.

Methods and activities of many research organizations, industrial companies and other technical groups working in the field have been surveyed.

PLANT TRIPS

Monday, AM, **Firestone Tire and Rubber Co.** PM, **Institute of Numerical Analysis Research, UCLA.**

Tuesday, AM, **Douglas Aircraft Co.** PM, **Lever Bros.**

Wednesday, AM, **Shell Chemical Corp.,** (Syn. Rubber). PM, **CBS Television City.**

LADIES PROGRAM

Sunday, 5:30—7:30 PM, **General Cocktail Party.**

Monday, 10:00 AM, **Tour Palos Verdes Estates,** Oceanarium, lunch at Marineland Restaurant, Wayfarer's Chapel, Portugese Bend, etc.

Tuesday, 1:00 PM, **Pasadena Tour,** including Huntington Gardens, San Gabriel Mission, tea at Mr. Benjamin Holt's residence in South Pasadena.

Coffee hour every morning in Boston Room of the Statler.

Atomic Exposition Demonstrates Industry Believes Sizeable Business Volume Near

The big nuclear question is—What does American industry have to sell in the way of products for an atomic future?

At the Cleveland Atomic Exposition the answer appeared clear: A great deal, judging from the 162 exhibits, the products ranging from remote "arms" to complete reactor power plants.

With stakes as large as they are, manufacturers seem to be taking no chances, wasting no time, in laying the groundwork for production of their own particular equipment and services, but *are* taking chances on just what systems to back. The theory, according to one manufacturer, is that the firms having the longest experience with the designs and systems ultimately favored, will be in an advantageous position.

The Exposition had another interesting aspect—Much of the equipment shown had either obvious or possible application in non-nuclear installations. Attention paid by attendee engineers to the canned-rotor pumps, corrosion-and-heat-resisting materials of construction, and specialized heat transfer devices, gave evidence of the intense interest in such dual-purpose items.

Vital Statistics

Score for the Exposition: 21,991 total attendance, of which 16,157 saw Exhibition only; 2,834 registered for both Exposition and Congress; 3,000 were students who arrived by busloads and were shown through the first two days (by cooperation with local educational groups). Report from exhibitors: Satisfaction with both quality and quantity of attendance. (For comments, see p. 53.) Conclusion: Success—which resulted in immediate formation of plans for another to take place in Philadelphia, first week in October.

(*Pictures on page* 53)

Chemical Exposition Showed Advances in Equipment

As was expected, the Chemical Exposition in Philadelphia displayed numerous advances in processing equipment. Among these were: An improved finned tube (Brown Fintube), a glass-packed, glass-lined Turbogrid column section (Pfaudler), a new expanded-metal tower packing (Spraypack, Blick-

(*Continued on page* 50)

Nuclear Congress a Forum for Different Approaches to Economic Power

A combination of engineers' and scientists' implementations, intermixed with world leaders' cautions, would be one way to describe a Congress so large and diversified as to be almost uncharacterizable.

International Atom

If the myriad technologic paths toward economic generation of power from the atom seemed confusing, there was clarity in the international situation as described by A.I.Ch.E. Nuclear Engineering Division banquet speaker, Gunnar Randers. Special assistant on peaceful uses of atomic energy to U.N. Secretary-General Hammarskjold, Randers cautioned against optimism for the really "underdeveloped" nations of the world to quickly benefit from nuclear energy. Reason for this is explained by grouping nations into four categories: Those having both nuclear fuel and reactors in which to use it; those having raw fuel but no reactors (but having a bargaining position for the latter); those having neither nuclear fuel nor reactors but having industrial skills and sufficient other raw materials to enable them to trade products for nuclear fuels and reactors; and those without either natural resources or skills. The hope

Nuclear Eng. Div. dinner group—l. to r., Katz, Dunning, Randers, Genereaux and Dodge.

for the latter through the advent of nuclear power will be no greater than has been the case with more conventional sources of power. In other words, such nations have nothing to trade in exchange for the investment in nuclear power generation installations. No power generating reactors, commented Randers, can be expected to be located in the center of barren deserts.

Another aspect of Randers remarks had to do with the caution being exercised by the Western nations in their desire to make sure that reactors (which are capable of producing plutonium) will not fall in the hands of people who might use the plutonium produced as a byproduct to produce bombs.

Nuclear Institute

On the national scene, Admiral Lewis L. Strauss, chairman of the Atomic Energy Commission, announced at one of the dinners that an institute for faculty members of American engineering colleges and universities will be established this summer at Argonne National Laboratory, near Chicago. Purpose will be to alleviate the shortage of teachers qualified to instruct in nuclear technology. Action was said to have been taken after consultation between the A.E.C., National Science Foundation, and the A.S.E.E.

Strauss—"Where are men, proficient in this new art, to be found?"

Productive Future

President Eisenhower sent his greetings to the Congress, citing that he had been advised that by 1965, "peacetime atomic energy will represent an investment of many hundreds of millions of dollars. Future expansion will depend on how well we are able to add more scientific and engineering brain power to our engineering force in order to make a more productive atomic future possible."

Likewise, Walter G. Whitman, Conference Secretary General of the U.N. Geneva meeting on peaceful uses of Atomic Energy, sent a message which termed the Cleveland meeting one which should "mark a distinct advance towards the engineering application of this revolutionary source of energy to the benefit of mankind."

"Declassify"—Anderson

Difficulties experienced in getting information needed for industry to proceed with commercialization of atomic energy, were laid at the door of the A.E.C. by Senator Clinton P. Anderson (D.-N.M.), in an address before another of the dinner groups. That indecisions with respect to prices and availabilities of fuel for use in reactors offered for sale abroad is holding back our indus-

(*Continued on page* 50)

RECENT MEETING...

congress a forum

(*Continued from page* 49)

try's ability to sell the reactors, was cited as an example. On the subject of peaceful uses of energy from thermonuclear reactions, Senator Anderson said, "It is my considered opinion that the time has now arrived when we should declassify, and not merely downgrade, all our work in the controlled hydrogen field."

Attendance High

With regard to the Congress sessions, they were well attended, with those of wider interest (according to nature of subject) running as high as 300 in the audience, consistently.

Preprints were in brisk demand (see picture)—the A.I.Ch.E. not only handling the sales, but having underwritten the printing of both preprints of papers and programs for the Congress.

Van Antwerpen and preprints—"A big job, but evidently very much worth while, judging from the response."

That this joint effort of so many engineering and scientific societies did "come off" so smoothly, is attributable not only to the belief of so many in the cause involved, but, as usual, to the dedication and willingness to take responsibility on the part of a handful of people. For the Congress, the services of Donald L. Katz (Univ. Michigan) as program chairman, was outstanding. Likewise, for the Nuclear Engineering Division of the A.I.Ch.E., the efforts of R. P. Genereaux went far in making the A.I.Ch.E. contribution—which was no small one any way measured.

chemical exposition

(*Continued from page* 49)

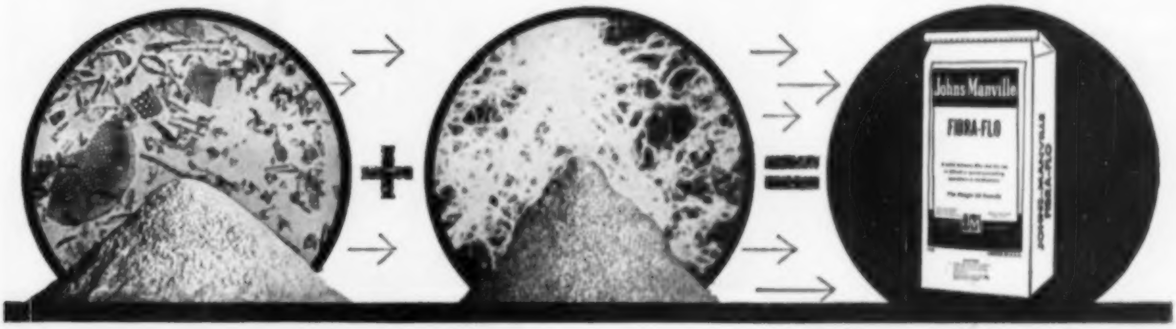
man), larger diameter fused quartz scrubber and heat exchanger (Amersil), and others too numerous to mention in the brief survey made.

Our attention was directed primarily to the quality of exhibits, from the standpoint of how well they demonstrated worthwhile engineering information. For pictures, see page 52.

Johns-Manville announces a new line of Filter Aids

FIBRA-FLO

For . . . *Exceptional Clarity, Cake Stability, Labor and Maintenance Savings*



DIATOMITE—Celite's unique particles provide highest clarity at fastest flow rates.

ASBESTOS—Fibrous asbestos particles provide greater cake stability and adsorption.

FIBRA-FLO—In Fibra-Flo you get the advantages of both asbestos and diatomite.

Combining the excellent adsorption properties of selected and processed asbestos fibres with the high flow rates of Celite* diatomite, Johns-Manville offers this PRE-MIXED filter aid to those requiring superior filtration of liquids.

Johns-Manville, the world's largest producer of both Asbestos AND Diatomite, selects materials from each of its mines and carefully blends them into a number of grades. In addition, strict uniformity is maintained for each grade so that you may choose the exact mixture you require, relying on this uniformity for all future orders.

Fibra-Flo is now available in carload quantities. Use the coupon below to get further information.

FIBRA-FLO offers the following advantages to your filtration process:

1. Improved clarity more quickly obtained.—Increased production.
2. Filter cake more easily parted from screen.—Labor savings.
3. Better protected septums, less plugging.—Labor and maintenance savings.
4. Screen imperfections can be coated.—Longer service.
5. Asbestos can adsorb undesirable dissolved solids.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville

FIBRA-FLO

asbestos-diatomite filter aids

A product of the Celite Division

*Celite is Johns-Manville's registered trademark for its diatomaceous silica products.

Johns-Manville, Box 60, New York 16, N. Y.
(In Canada: Port Credit (Toronto) Ontario.)

☐ Please send further information on Fibra-Flo
☐ Please have Celite technical man call for appointment

I am interested in the filtering of____________________

____________________ with the following equipment

____

Name________________ Title__________

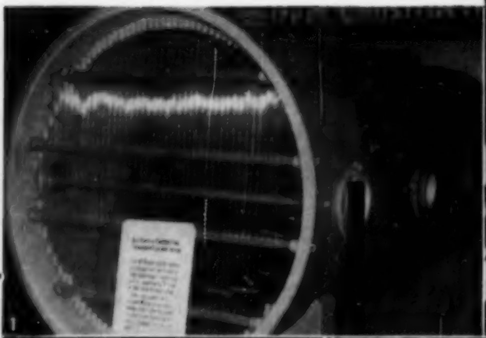
Company________________ Address__________

City________________ Zone______ State______

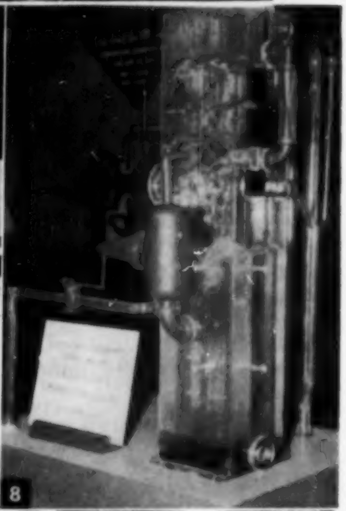
Philadelphia

CHEM SHOW

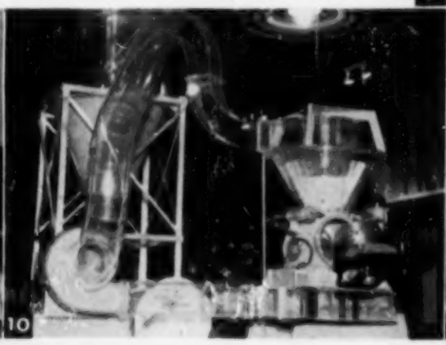
As promised (Opinion & Comment, C.E.P. Nov. 1955) we looked over the exhibits from a quality standpoint, photographed the outstanding ones. Our congratulations to those exhibitors whose displays are shown; our apologies to those which space did not permit showing.

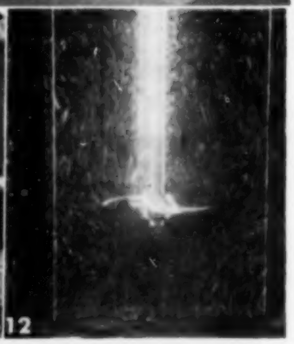


1. The Pfaudler Co.
2. "Yorkmist" demister, Otto H. York Co., Inc.
3. V. D. Anderson Co.
4. Corning Glass Works
5. Claude B. Schneible Co.
6. "Spraypak," S. Blickman & Co.
7. S. Blickman & Co.
8. Ingersoll-Rand



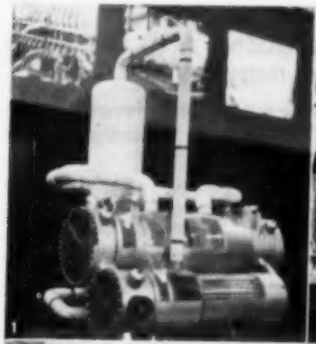
9. Corning Glass Works
10. Hardinge Co.
11. Williams Patent Crusher & Pulverizer Co.
12. Mixing Equipment Co.

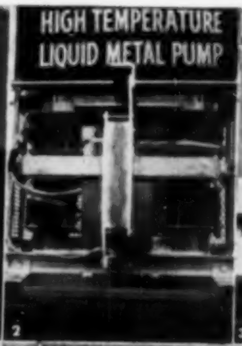


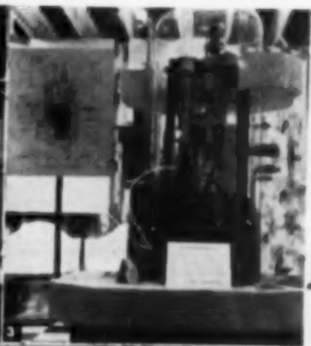


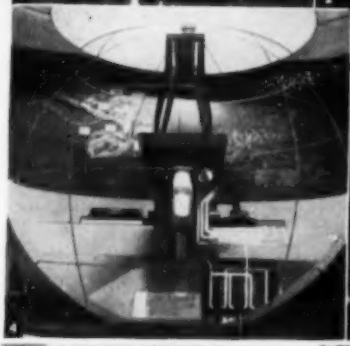
Cleveland

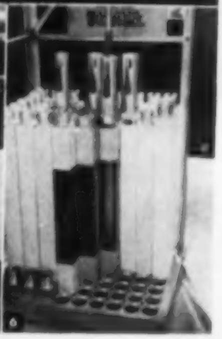
ATOMIC EXPOSITION











OPINIONS

". . . major success." L. Smiley, *Sylvania*.

". . . [Exhibits of] high quality and pertinence . . ." R. F. Eisele, *Leeds & Northrup*.

". . . impressive number and variety of customer companies' engineers . . ." E. D. Kane, *Cuno Engineering*.

". . . real contribution to the industry . . ." F. W. Claus, *Foster Wheeler*.

"Very worthwhile . . . will become one of the largest in the U. S." G. M. Butler, *Electronics Division, Curtiss-Wright*.

1. Griscom-Russell Co.
2. Callery Chemical Co.
3. Atomic Power Development Associates
4. General Electric Co.
5. Escher Wyss Ltd.
6. Bendix Aviation Corp.
7. New York University "Pickle-barrel" subcritical nuclear reactor.
8. Atomics International

9. Sylvania Electric Products Co.
10. Allis-Chalmers

11, 12, 13. Gunnar Randers, banquet speaker from UN, being shown through Exposition by R. P. Genereaux. Finally, off for Norway, carrying a complete set of Congress preprints to his overseas colleagues.

THE STUDENT AND THE MAN FROM INDUSTRY

Students meet experienced engineers at Detroit "meeting with a difference."

Chemical engineering students, who often have moments of wondering what life in industry will be like, had a chance to find out, rub shoulders with their experienced elders, at a recent "experimental" student meeting in Detroit.

The meeting, a one-day affair held at the A.I.Ch.E. Annual Meeting, was directed toward orientation for future entry into industry through talks and counseling. But it had a bonus—a bonus in human relations.

The "different" aspect of the meeting arose in the handling of the student banquet, and in the efforts of a number of men (H. J. Peddicord, R. M. Lawrence) and companies (Procter & Gamble, Wyandotte, respectively) to foster student-engineer contact by acting as sponsors for students, paying transportation and other expenses.

At the banquet itself—brainchild of H. G. Donnelly, Wayne University—industry engineers picked up checks for students in advance, assumed social and professional responsibility for them, sat with them, generally established close rapport.

Speaker S. D. Kirkpatrick, McGraw-Hill, and past A.I.Ch.E. president, continued the theme of human relations within chemical engineering by talking of "fringe benefits" in professional society membership.

Lawrence also stressed, in his talk, the importance of the relationships established in society membership and meetings by describing his own experiences as a student attending society meetings. His greatest gain: talking with leaders in the field, meeting the men who would be his associates throughout his professional career.

CORRECTION

Incorrectly captioned as the main building of Food Machinery & Chemical's new Central Research Laboratory, (December, 1955, p. 42), was the main building of U. S. Industrial Chemicals' new pilot plant.

Food Machinery's new building appears in the architect's drawing above.

THIS VALVE HAS 3,500 FATHERS

More than 3,500 users, specifiers and buyers have had a hand in the design of the Cooper Alloy stainless steel valve. We're proud of the fact that many of the design features it embodies owe their origin to your suggestions and we are equally proud to learn that our valve clinics have helped to reduce maintenance costs in your plants.

These Valve Clinics have been held in most major industrial centers and our in-plant clinics have been held on the spot in dozens of leading industrial plants.

Arrangements for a valve clinic in your own plant similar to those already held at DuPont, Pfizer, Celanese, Standard Brands, and many others, may be made through our Public Relations Division.

"75 Questions". . . a selection of those questions asked most often at our clinics, is available on request.

Valve & Fitting Division

COOPER ALLOY
CORPORATION • HILLSIDE, N. J.

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD
First Class Permit No. 48890, Sec. 34.9, P. L. & R., New York, N. Y.

Postage Will Be Paid by Addressee

CHEMICAL ENGINEERING PROGRESS
25 West 45th Street
New York 36,
New York

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD
First Class Permit No. 48890, Sec. 34.9, P. L. & R., New York, N. Y.

Postage Will Be Paid by Addressee

CHEMICAL ENGINEERING PROGRESS
25 West 45th Street
New York 36,
New York

the chemical engineers'

DATA SERVICE

and

GUIDE

to significant developments in

- **EQUIPMENT**
- **MATERIALS**
- **SERVICES**

developments of the month–

99 An entirely new concept in the loading and unloading of chemical and petroleum products is incorporated in a new device known as the Chiksan Hydraulically Controlled Marine Loading Arm. Designed to speed up tanker operations while providing an unusually high degree of safety to dock workers and equipment, the Loading Arm is the result of ten years research and development by Chicksan Co., Brea, Cal. Mounted on a structural steel frame some ten feet from the water's edge, the Loading Arm consists basically of two lengths of aluminum pipe of six, eight, or ten inch diameter. These are coupled together by Chiksan aluminum swivel joints. A boom and cam arrangement, powered by hydraulics, enables one man at a remote control point to place the flanged end of the arm aboard the largest existing tanker in one minute.

Once aboard and attached, the power system on the arm is placed in free-wheeling, allowing for a forty foot rise and fall of the ship, a lateral drift of twenty feet, during operations. In free wheeling, operation may proceed unattended. As many as seven arms can be operated from one set of controls.

Other advantages of the new Loading Arm include: large savings in man-power; no down-time or product loss from bursting hoses; and many more.

For further details, performance data, circle number 99 on Data post card.

(Continued on page 58)

TURN THIS PAGE TO RIGHT FOR MORE . . .

HOW TO USE THIS POST CARD FOLDER

Merely encircle numbers on cards to get literature desired. On advertised products in front of magazine, fold this page out to right. For those in back, fold card strip again to right, where card strip is scored for detaching.

products-

advertised in this issue

IFC Acrolein Derivatives. Pentanediol & glutaraldehyde are produced in development quantities. Chlorallylidene diacetate in research quantities. Samples & information available. Carbide & Carbon Chemical Co.

3R Rotary Sifter. Model M Bar-Nun incorporates all requirements for a screening job. Classifies, screens, sizes. B. F. Gump Co.

4A Automatic Control. Using Varitrol as a component of U. S. Varidrive controls motor speeds. Adaptable for constant pressure, proportional flow & many others. U. S. Electrical Motors Inc.

6A Valves. Hot phenol is rough on valves. These valves handle phenol at 350° F. without trouble. Crane Co.

7A Filters. Units from Process Filters, Inc. assure efficient, trouble-free, high production. Variety of types. Process Filters, Inc.

8A Dowtherm. An ideal transfer medium for high temperature, low pressure heat. For steam at 700° F. exerts pressure of 3,000 lb./sq.in. Dow Chemical Co.

9A Nitric Acid. A pressure process from Chemical & Industrial Corp. is illustrated.

10A Leakproof Pump. Extension of applications is now made possible by new design features. Investigate this low-cost sealless pump. Chempump Corp.

11A Filters. Available from Dollinger Corp. all types of filters illustrated plus special units for particular filtration problems.

12L Packaged Plants. Whether your need arises from a new process or expansion of your facilities Doyle & Roth are prepared to furnish packaged plants.

13A Rectifiers. No delicate adjustments needed. Unique plunger starts continuous excitation. Allis-Chalmers.

14A Lithium. A well-known element with many new uses. Its future is infinite. Used in high temperature alloys, propellants, chemical processes. Lithium Corporation of America, Inc.

15A Flaker. From F. J. Stokes Machine Co. The flaker unit replaces batch method in processing of naphthalene. Booklet & other information available.

16A Fume Scrubber. The problem of pungent fumes in industry is easily solved by absorption using the fume scrubber. Rubber lined, unit resists corrosive action & fumes. Schutte and Koerting.

17A Pulsafeeder. Now a controlled-volume proportioning pump for laboratory use, pilot plants & industrial production. Capacity 2,150 ml./hr.; maximum discharge pressure 1,000 lb./sq.in. gauge. Lapp Insulator Co., Inc.

18L Pulverizer. Ultrafine grinding with controlled particle size distribution is now available in Schutz-O'Neill Co. Superfine pulverizers. Free test grind.

19A Lead Shielding. Extruded lead bricks have no hidden voids or shrink-holes to lessen protection. Available in standard sizes either flat-side or curved Protecto brick. National Lead Co.

20L Oil Reclaimers. The Hilco unit purifies by continuous recirculation either on full-flow or by-pass basis or intermittently on batch basis. A type for every job. Hilliard Corp.

21A Electrodes, Anodes, Mold Stock. Products in carbon & graphite distinguished by integration between research discoveries & process refinements of raw materials. Great Lakes Carbon Corp.

22A Drying Equipment. Efficient drying often results in more profit. Proctor & Schwartz, Inc. equipment provides control, flexibility & features essential for this end.

23A Fluid Agitator. An integrated, packaged fluid agitator service now available from Philadelphia Gear Works, Inc. Many exclusive features.

24L Tube Mills. Units for wet or dry grinding in sizes 2 to 10 ft. in diameter; 6 to 35 ft. long; single or multiple compartments; acid proof linings of rubber, silica & porcelain. Hardinge Co., Inc.

25A Filters. Increased production results from improved design of these units. With longer runs bottlenecks are broken & maintenance reduced. R. P. Adams Co., Inc.

26A Stainless Steel. Bars, sheets, plate, heads & other shapes in stainless steel available from G. O. Carlson, Inc. Complete service with emphasis on flexibility, efficiency & economy.

27A Speed-Lock Cover. A new concept in pressure vessel closure with eight advantageous features. Sparkler Mfg. Co.

28L Methyl Mercaptan. Material is now available in small lots or tank cars from Pan American Chemicals Corp.

29A Fatty Acid Process Units. Foster Wheeler Corp. designers of low-cost distillation plants are responsible for another fatty acid plant with rated capacity 1,500 lb./hr. crude fatty acid.

30A Valves. A high quality, low-cost, & easily installed Tube Line valve in sizes for 1/8 to 1/2 O.D. tubing. Stainless steel construction. Autoclave Engineers, Inc.

32A Mist Eliminators. Schuylernit units for the chemical & petroleum industries are custom designed & constructed for economical separation of liquid & small particles. Schuyler Mfg. Corp.

2J Dryers. High-speed conveyor & truck type dryers with many exclusive features. Assure low operating costs & improved product. National Drying Machinery Co.

33A Fume Washer. Called Cycloneire this compact, portable fume washer fits anywhere but does a big fume removal job. Removal effective to 99.9%. U. S. Stoneware Co.

35A Silica Gel. Davison Chemical Co. silica gel gives a high capacity for moisture even at temperatures of 110-120° F. Economical for drying natural gas.

36A Stainless Steel Tubing. Service conditions in refinery applications require durable tubes. Stainless tubing served 100 hrs. at pressure of 10,000 lb./sq.in. & temperature of 1,100° F. before failure. Babcock & Wilcox Co.

37A Graphite Equipment. Fabricated from Karbate impervious graphite process equipment from National Carbon Co. gives unequalled corrosion-resistance & immunity to thermal shock.

DEVELOPMENTS OF THE MONTH *(Cont.)*

100 A new continuous turbulent floating blade evaporator, permitting the thinnest possible films on the heat transfer cylinder and smaller amounts of material in process, has just been developed by the Rodney Hunt Machine Co., Orange, Mass., was introduced at the recent Chemical Exposition.

Designated the Turba-Film Floating Blade Evaporator, the new unit is said to be ideal for reduction of solutions from which the intermediate product is to be a mixture of crystals and liquor. But in some instances it is possible to produce a dry powder.

The blades, which are pivoted so that they ride on a thin film of liquid flowing down the heat transfer cylinder, are constructed of various materials depending on the process.

The evaporator is adapted especially to the separation by distillation of heat sensitive materials which tend to decompose or polymerize.

Because of its construction, the new evaporator controls foaming so as to entail no loss, and prevents the formation of crust or coke on the walls of the heating chamber.

The unit is available in 7 sizes with varying cylinder diameters and heating areas.

For further details circle number 100 on Data post card.

101 If you have operations which require an **oven having adjustable temperature control from 100° F. to 1000° F.,** Grieve-Hendry Co., Chicago, has designed one especially for you.

Gas fired, the oven is all steel, insulated with 5 inch Rockwool. Partlow temperature controller is standard equipment.

The oven can be built to operate electrically, size of work space is 26" x 30" x 30".

For full details circle number 101 on Data post card.

(Continued on page 60)

38L Mechanical Seal. A pressure-balanced bellows design seal said to give unsurpassed performance & have long, trouble-free life. U. S. Gasket. Belmont Packing.

39A Corrosion. A report on progress against corrosion in 1955, available from Pfaudler Co. manufacturers of glassed-steel & acid-alkali-resistant glass equipment.

40A Process Equipment. M. W. Kellogg Co. have expanded their fabricating facilities to produce shells thicker & bigger, in less time.

41A Synthesis Gas Plants. Girdler Co. specialists in design, erection & operation of synthesis gas plants announce a recent installation for production of mixture of hydrogen & carbon monoxide.

42L Transmitters. Units said to give successful performance under extreme conditions. Accurately transmit flow, liquid level, and/or differential pressure with high speed. Barton Instrument Corp.

45A Process Plants & Equipment. Badger Mfg. Co. prepared to supply the precious plus which does not appear on the blueprints. Investigate.

Stainless steel filter—see item number 4, page 62.

47A Filters. Built to meet exacting requirements Eimco Corp. filters give guaranteed performance. Many designs available.

48A Evaporator-Crystallizers. Units fabricated from stainless steel alloy which operate under non-scaling conditions another "first" for Struthers Wells Corp.

50L Grinders & Mixers. A unit to meet every need. See illustrations & details in ad of Paul O. Abbé, Inc.

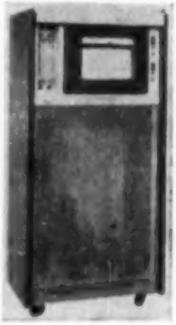
51A Filter Aids. Announced by Johns-Manville a line of filter aids called Fibra-Flo. Use results in exceptional clarity, cake stability, & savings.

54L Heat Exchangers. Fabricated from Impervite an impervious graphite a variety of corrosion-resistant heat exchangers. All tubing is extruded. Falls Industries, Inc.

55A Valve. A stainless steel valve designed as a result of valve clinics & said to embody features resulting in efficiency & maintenance reduction. Cooper Alloy Corp.

56A Nickel Alloyed Stainless. Castings which safely handle corrosives fabricated from this material. Resists hot H_2SO_4 even when turbulence speeds the attack. International Nickel Co., Inc.

61A Spray Dryer. Developed by Bowen Engineering Inc., a semi-works spray dryer which is compact, gives high yield, is easy to clean & is operated at low cost.



Oxidant recorder—see item number 8, page 62.

Numbers without letters indicate data available as described in Data Service "Briefs." Numbers with letters refer to further data concerning products advertised in this issue. Letters indicate position of advertisement on page (if more than one on a page)—L, left; R, right; T, top; B, bottom; A indicates full page; IFC, IBC, and OBC are cover advertisements.

Please do not use this card after April, 1956

1	2	3	4	5	6	7	8	9	10	11	12	14	15
16	17	18	19	20	21	22	23	24	25	26	27	28	29
30	31	32	33	34	35	36	37	38	39	40	41	42	43
44	45	46	47	48	49	50	51	52	53	54	55	56	57
58	59	60	61	62	63	64	65	66	67	68	69	70	71
72	73	74	75	76	77	78	79	80	81	82	83	84	85
86	87	88	89	90	91	92	93	94	95	96	97	98	99
100	101	102	103	104	105	106	107	108	109	110	111	112	114
115	116	117	118	119	120	121	122	123	124	125	126	127	128
129	130	131	132	133	134	135	136	137	138	139	140	141	142

Advertisers' Products

IFC	3R	4A	6A	7A	8A	9A	10A	11A	12L	13A
14A	15A	16A	17A	18L	19A	20L	21A	22A	23A	24L
25A	26A	27A	28L	29A	30A	32A	2J	33A	35A	36A
37A	38L	39A	40A	41A	42L	45A	47A	48A	51A	54L
55A	56A	61A	63A	65A	66L	67R	68L	68R	69R	70TL
70BL	70TR	70BR	71R	72TL	72BL	73R	74L	74BL	75R	76L
77R	78L	79R	80L	81R	82TL	82BL	83R	84L	85R	86L
87R	88TL	88BL	89L	89R	90L	90TR	90BR	91TR	91BR	98L
98R	99R	IBC	OBC							

Chemical Engineering Progress Data Service

Name ....

Position ....

Company ....

Address ....

City .... Zone ..... State ....

☐ I want a subscription. Bill me $6.00 for a year.

January, 1956

Please do not use this card after April, 1956

1	2	3	4	5	6	7	8	9	10	11	12	14	15
16	17	18	19	20	21	22	23	24	25	26	27	28	29
30	31	32	33	34	35	36	37	38	39	40	41	42	43
44	45	46	47	48	49	50	51	52	53	54	55	56	57
58	59	60	61	62	63	64	65	66	67	68	69	70	71
72	73	74	75	76	77	78	79	80	81	82	83	84	85
86	87	88	89	90	91	92	93	94	95	96	97	98	99
100	101	102	103	104	105	106	107	108	109	110	111	112	114
115	116	117	118	119	120	121	122	123	124	125	126	127	128
129	130	131	132	133	134	135	136	137	138	139	140	141	142

Advertisers' Products

IFC	3R	4A	6A	7A	8A	9A	10A	11A	12L	13A
14A	15A	16A	17A	18L	19A	20L	21A	22A	23A	24L
25A	26A	27A	28L	29A	30A	32A	2J	33A	35A	36A
37A	38L	39A	40A	41A	42L	45A	47A	48A	51A	54L
55A	56A	61A	63A	65A	66L	67R	68L	68R	69R	70TL
70BL	70TR	70BR	71R	72TL	72BL	73R	74L	74BL	75R	76L
77R	78L	79R	80L	81R	82TL	82BL	83R	84L	85R	86L
87R	88TL	88BL	89L	89R	90L	90TR	90BR	91TR	91BR	98L
98R	99R	IBC	OBC							

Chemical Engineering Progress Data Service

Name ....

Position ....

Company ....

Address ....

City .... Zone ..... State ....

☐ I want a subscription. Bill me $6.00 for a year.

January, 1956

products-(Cont.)

63A Centrifuges. No matter what your problem Sharples Corp. can supply a unit to do your job continuously at low cost. Bulletin on complete line.

65A Stainless Steel. Many industries require solid stainless. In some operations stainless cladding does the job & cuts cost. Sun Shipbuilding & Dry Dock Co. fabricates solid stainless as well as alloys.

66L Pumping. A progress report on pumping is featured by Aldrich Pump Co. A reading will tell you how you may overcome specific problems.

67R Tantalum. You need tantalum in your process if its use eliminates shutdown, contamination, & other waste due to corrosion. Book available on use in chemistry. Fansteel Metallurgical Corp.

68L Liquid Level Control. Unit called Magnetrol said to be as dependable as magnetic force no matter how specialized your application. Magnetrol, Inc.

68R Tetrines. Use of Glyco Products Co., Inc., ethylene-diamine tetraacetic acid & salts act to prevent curd, scum, & haze formation & dissolve if when present. Purest commercial forms available.

69R High Alloy Castings. Large, small or special shapes which are corrosion, heat & abrasion resistant, fabricated to your order. Melt, casting & finishing controlled & tested. Duraloy Co.

70TL Laboratory Glassware. The Diamond D Blue line glassware from Doerr Glass Co. has carefully calibrated gradations, is uniformly accurate, has precision craftsmanship built in.

70BL Fin & Pipe Coils. Built from stainless steel units handle many corrosive air mixtures or liquid to be heated or cooled. Data book prepared for special use of design engineer. Rempe Co.

70TR Aerating & Level Indicator Units. From Bin-Dicator Co. a Bin-Flo aerating unit for steady flow of dry, finely ground materials. Bin-Dicator is a bin level indicator for all bulk materials. Detail data book available.

70BR Spray Nozzles. Wide choice of spray nozzle types & capacities meet your needs exactly. Also a line of strainers available from Spraying Systems Co. & covered in their complete catalog.

71R Heat Exchangers. Loss of heat transfer resulting from slime formation on condenser & heat exchanger waterside surfaces eliminated by chlorination of cooling water. Information available. Wallace & Tiernan Inc.

72TL Process Equipment. Added to a line of pressure vessels & tanks built to ASME code, Washington Aluminum Co., Inc. has available aluminum grating walkway & handrailing.

72BL Mixer. Use of Hermes Machine Co. jet mixer circulates the mass material evenly. No vortex or surface boil. No entrapped air to oxidize compounds.

73R Centrifugal Pumps. A complete line of Westfalia's continuous clarifiers & separators available to solve your problem. Free literature available. Centrico Inc.

74L CO_2. A substance with amazingly diversified talents it has unlimited applications which are described in a new booklet from Liquid Carbonic Corp.

74BR Ejectors. Steam-jet ejectors with sustained high efficiency are built with nozzle which prevents possible internal leakage. Ingersoll-Rand.

75R Process Equipment. Whether your need is for a kettle, reboiler, reactor or other unit Manning & Lewis Engineering Co. is ready to design & fabricate it for you.

76L Linings & Coatings. Various types of materials for prevention of corrosion available from Atlas Mineral Products Co. Bulletins on each material give technical information.

77R Heat Exchanger. Called Paracoil this self-cleaning heat exchanger eliminates down time where tube fouling is present. Davis Engineering Corp.

78L Jacketed Pumps. These pumps designed for pumping various chemicals which tend to solidify & become viscous at low temperatures. Bearings are heavy-duty, water-cooled. Lawrence Pumps, Inc.

79R Heat Exchangers. Fabrication from special heat exchanger materials is the specialty of Downingtown Iron Works, Inc. Some stainless steel units provided with enamel-lined tubes for solving specific problems.

80L Fused Silica Lab Ware. Vitreosil ware (pure fused silica) meets exacting laboratory needs. Also prepared to fabricate special items in addition to large line available. Thermal American Fused Quartz Co., Inc.

81R Vaporizers. Units of a variety of types for handling chlorine & ammonia. Heavy duty type built to individual requirements. Richard M. Armstrong Co.

82TL Relief Valves. For safety at pressures to 45,000 lb./sq.in. use adjustable relief valves. Parts have Stellite stems & seats. Available in three pressure ranges. American Instrument Co.

82BL Rotary Presses. Available from Arthur Colton Co. rotary presses with capacities 65 to over 5,000 tablets/min. Also a line of mixers, granulators & ovens for high production at low cost.

83R Ball Joints. For use in piping handling chemicals Barco Mfg. Co. flexible ball joints. Bodies of stainless steel. Also available in other materials. One ball joint said to do the work of two swivel joints.

84L Reaction Flasks. From Ace Glass Inc. reaction flasks with heads interchangeable with bottoms. Large necks for easy cleaning. Capacities & types for every need.

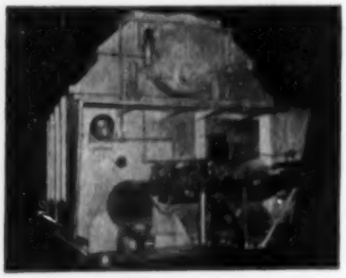
85R Cooling Towers. Built by specialists in the field the Marley Co. has a factory-trained man standing by at each operation to see that every vital component functions properly.

86L Silicone Defoamers. Production goes up when foam goes down as a result of using one of three Dow Corning Corp. silicone defoamers. Equally effective at low concentrations.

87R Filters. You can now have continuous filtration 24 hours a day using Filtration Engineers, Inc. string filters. Small pilot plant filter available on rental basis.

(Continued on page 62)

DEVELOPMENTS OF THE MONTH *(Cont.)*



102 To provide accurately controlled temperatures over a broad range, Union Iron Works has designed a new Packaged Vaporizer, Type MH, for use with Dowtherm "A" or "E", Para-Cymene, or Anisole.

The company claims that, unlike steam generators, the new Vaporizer can be used to obtain extremely high temperatures at low pressure, and unlike direct-fired methods, control is simple, sensitive and uniform.

Furnished for heating with oil, gas, waste heat or special fuels, depending on the particular application contemplated, the new Unit operates with a slight positive pressure in the furnace. Need for an induced draft fan is eliminated; stack height is materially reduced.

Featuring compact, three-drum design, the Vaporizers are completely shop-assembled and shipped as packaged units for indoor or outdoor installation to meet requirements from 3,700,000 to 15,000,000 BTU/hr.

Divided tube banks enclose the furnace, and the straight-through gas flow over the tube banks requires furnace baffles only. This straight line tube pattern provides high heat transfer without the higher draft losses of a staggered tube arrangement.

For fully illustrated bulletin, and further details circle number 102 on Data post card.

(Continued on page 62)

products-(Cont.)

88TL Filter Presses. A type & capacity unit is available to meet practically all conditions of pressure & temperature, clarity & flow rate of filtrate, etc. from laboratory to plant operation. T. Shriver & Co., Inc.

88BL Sprocket Rim. Every valve said to be easily accessible with Babbitt Steam Specialty Co. adjustable sprocket rim with chain guide. Redesigned for greater strength & easier, more solid assembly.

89L Sinks. Whether you are looking for sinks, process equipment, materials of construction or engineering services refer to Chemical Engineering Catalog published by Reinhold Publishing Corp.

89R Gages. Jerguson Gage & Valve Co. will help you solve problems of accurate gaging of levels & pressures when liquids are cold & slow, or hot & fast. Some units available with electric heating. Special details available.

98L Storage Tanks. Called Pla-Tank units are often chosen for chemical storage. Resistant to variety of acids, fumes & temperatures. Stacks, hoods, ducts also available. Pla-Tank, Inc.

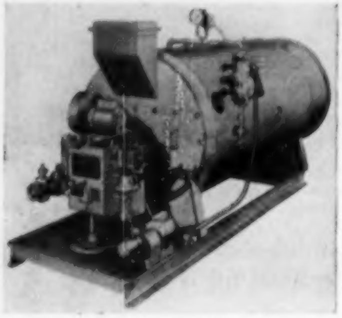
98R Ion Exchange. Now a new deionizer unit on wheels makes it possible to accomplish deionizing anywhere. A general purpose unit. Available in two- or mixed-bed models. Illinois Water Treatment Co.

99R Steam-Jet Evactors. Chill-Vactor is only one of this type unit manufactured by Croll-Reynolds Co., Inc. Has no moving parts & no chemical refrigerant used to accomplish chilling.

IBC Pumps. For downhill metering the new Milton Roy Co. Delta P pump. Features no stuffing box, running seal, contamination. Easily dismantled. Accurate to ±1%.

OBC Mixers. Do you want to outsmart fluid mixing costs? Then consider the Lightnin. Literature on mixing & these mixers available. Mixing Equipment Co., Inc.

DEVELOPMENTS OF THE MONTH *(Cont.)*



103 Need a dependable source of steam under all operating conditions—plus the added advantage of a self-contained unit ready to operate when received?

Eclipse Fuel Engineering Co., Rockford, Ill., has brought out a new line of Scotch type Steamboilerplants to do just that. Known as the "Red Band" line, they range in size from 12 to 25 hp, are for gas, oil, or combined fuel firing, are specifically designed for process heating application.

All necessary valves, controls and boiler trim are mounted on the unit, and internal piping and wiring is completed. Burner equipment is controlled automatically by steam pressure with minimum supervision by the operator, and when electricity, steam, water, and fuel lines are hooked up the boiler is ready to produce steam.

For complete information, additional details, circle number 103 on Data post card.

(Continued on page 64)

90L Spray Nozzles. You'll get the right nozzles for washing, cooling, & many other applications from Binks Mfg. Co. A size & spray pattern for every purpose. Catalog available.

90TR Technical Data Books. Lefax Publishers printers of pocket size loose leaf books of about 140 pages of technical data on the large variety of subjects listed.

90BR Vacuum Equipment. Jet-Vac Corp. offers in addition to vacuum equipment, a line of steam jet ejectors, also condensers.

91TR Process Plants & Equipment. If your interest is in a pilot or complete plant Artisan Metal Products, Inc. is equipped to design & engineer both plant & necessary equipment.

91BR Plastics. For corrosion resistance, for electrical insulation you can cut costs by using glass reinforced polyester, epoxy or phenolic laminates supplied by Carl N. Beetle Plastics Corp.

equipment-

1 Spray Dryer. Pilot plant size spray dryer, horizontal type with nozzle atomization for developing techniques for spray drying chemicals, pharmaceuticals, foods, & other materials announced by Buflovak Equipment Div., Blaw-Knox Co. Has all normal advantages of spray dryer plus three of significance in solution of drying problems. Has extreme flexibility, requires no extra head room, & is easily cleaned.

2 Mechanical Seals. Designed for use on process pumps a new series of Unitary mechanical seals from Garlock Packing Co. Bulletin includes complete information, also section drawings & diagrams. Feature one-piece assembly, pre-set at factory, Collett-type drive, external lock & drive, circulating connections in glands, & long life.

3 Centrifugal Pump. Classed as a paper stock & industrial liquids pump unit features diverging type impeller enabling pump to handle liquids containing high concentrations of solids, air & gases. Pump is a horizontal, single-stage unit, available in sizes 4 to 12 in. with capacities from 200 to 7,000 gal./min., heads from 5 to 225 ft. Ingersoll-Rand Co.

4 Stainless Steel Filters. Cuno Engineering Corp. makes available a new line of porous stainless steel filters, Poro-Klean. Permit filtering under severe conditions—temperatures to 1,200° F., pressures to 2,000 lb./sq.in. of corrosive liquids or gases. Filter elements produced from spherical powdered stainless steel alloys.

5 Dust Filters. A newly designed housing available for the all housed reverse jet dust filters developed by Day Co. features a walk-in access door & two inspection doors. Speeds inspection. Bulletin 559 explains in detail distinguishing features of reverse jet filters.

6 Gate Valve. From Hamer Valves, Inc., a gate valve which provides impenetrable line shut-off. Packing seals of Teflon. Stainless steel locking rings & seats make unit impervious to corrosive fluids.

7 Swivel Joint. Called Swivel-Ette unit is of unique two-piece construction spun together when manufactured. Two types available in ½ & ¾ in. pipe sizes. For line where flexing & weaving are encountered. Rotates full 360°. Used for occasional or intermittent turning. Emsco Mfg. Co.

8 Oxidant Recorder. Instrument developed by Beckman Instruments Co. for study of various air pollution problems. May also be used for environmental testing of products affected by air pollution including rubber, plastics, agricultural crops. Measures concentrations as low as 2 parts per hundred million. Range of 0 to 80 parts per hundred million ozone equivalents may be extended.

9 Speed Controls. Complete 1 & 1½ h.p. Variac motor speed controls are small, rugged, & "drum" type used for forward, reverse, & stop operations. Dynamic braking resistor included for use where quick stopping is required. General Radio Co.

10 Packaged Liquid Chillers. Acme Industries, Inc. announces Flow-Therm packaged liquid chillers in capacities 15 through 300 tons. Series C has capacities of 20 through 175 tons; R series for remote compressor mounting—15 through 300 tons. Complete engineering data available.

11 Pipe Strainers. Development of six sizes of carbon moly steel strainers for use with oil, gas, air, water & steam lines for pressures to 900 lb. & temperatures to 900° F. Available either screwed or socket weld in sizes ½ through 2 in. Armstrong Machine Works.

12 Swivel Joints. Lightweight, low cost swivel joints designed for hydraulic or

(Continued on page 64)

equipment-(Cont.)

pneumatic service on pipe, tubing or hose developed by Barco Mfg. Co. Provide for up to 360° turning or rotating where flexible piping or tubing is required. Sizes ¼ through ¾ in. Binder insert catalog sheets show cutaway drawing, give dimensions & specifications, etc.

14 Infrared Analyzer. Designed for continuous monitoring & control of liquid & gas process streams. Especially suited for pilot plant operation unit said to be versatile & easily adaptable to determination of material balances & overall yields. Also useful in control of product purity & in fractional distillation columns. Beckman Instruments, Inc.

15 Tower Packing. Said to increase throughput up to 3½ times, material called Spraypak developed by S. Blickman, Inc. In large towers material is assembled in form of interlocking horizontal diamond-shaped cells placed adjacent to & over one another. Illustrated booklet describes material & construction, mechanical design, other details.

16 Scale Removal. A new method using chelating agents to remove mixtures of mineral & organic scale has been devised by Glyco Products Co., Inc. Based on amount of mineral scale present a stoichiometrically calculated amount of Tetrines is added to a 3 to 5% caustic or soda ash solution. Samples of Tetrines available.

17 Absolute Pressure Indicator. Added to line of Hastings Instrument Co., Inc., an indicator with range of 0.1 mm. to 20 mm. Hg & an expanded scale in the 0.5 to 5 mm. range. Direct reading, unit operates on 115 v. a-c. Incorporates usual Hastings heated thermopile principle.

18 Analog Field Plotter. Many complex field and flow problems can be solved by using electric current flow patterns set up in a sheet of thin conducting paper. Unit consists of complete package of components necessary for making such studies. Obtained answer is a visual, permanent record. Catalog describes equipment in detail. Sunshine Scientific Instrument.

19 Compound Drive Pulley. This variable speed unit with compound drive provides constant belt alignment through entire range up to 8:1 ratio. Using a 1,750 rev./min. motor, speed range of 5,550 to 690 is obtained at rated ¾ hp.; 1,150 rev./min. motor has speed range of 3,650 to 454 at rated ⅓ hp. Other information available in leaflet. Lovejoy Flexible Coupling Co.

20 Steam-Pyrolysis Process. A unique steam-pyrolysis process which permits of disposal of marginal products by economic conversion of natural gasoline, residuals, or other low value materials. Developed by the M. W. Kellogg Co. Booklet covers typical yields from steam cracking of ethane & propane, as well as other details.

21 Pyrometer. The development of a new type optical pyrometer designed for precision temperature measurements announced by Pyrometer Instrument Co., Inc. Meets need for higher degrees of accuracy & versatility in measurement of temperatures over 700° C. Measures targets less than .001 in. in diam. using supplementary lenses. Catalog.

22 Plate Fin Exchanger. Griscom-Russell Co. introduces an addition to the line a plate fin heat exchanger with extended surfaces on both sides. Designed for gas-to-gas service. Illustrated bulletin discusses design, applications, service conditions, other factors.

23 Dowtherm Vaporizers. International-LaMont Dowtherm vaporizers provide accurately controlled temperatures to 750° F. Forced recirculation provides positive protection from overheating. Bulletin available. International Boiler Works Co.

DEVELOPMENTS OF THE MONTH *(Cont.)*

104 A new standard line of control valves is claimed to be the first basic departure in control valve design.

Offered by the Hammel-Dahl Company. Some of the main features are: A new body design with extra large bowl capacity to insure a high coefficient of flow without involving excess body weight; all internal parts removable through the valve bonnet; and the ability to reverse action by inverting the superstructure.

Illustrated is a valve assembled for air-to-open action. By simply inverting this same topworks, without interfering with the open yoke or releasing compression of the stem packing, valve has air-to-close action.

For details and further information, circle number 104 on Data post card.

24 Conductivity Instrument. A Portable electrolytic conductivity unit designed for detecting salt water intrusions or presence of slugs of pollution in streams & wells announced by Industrial Instruments, Inc. Unit is lightweight, battery-operated, has portable AC bridge & weighted conductivity cell with extra-long extension cable.

25 Level Control. Fielden Instrument Div., Robertshaw-Fulton Controls Co. announce a level controller called Pneutronic which combines electronics & pneumatics to detect minute changes in levels in tanks, drums, process baths, & other conveyors. Eliminates use of servo motors & other rebalance mechanisms.

26 Proportioning Pump. Bulletin from Proportioneers, Inc. describes model 1105 Adjust-O-Feeder designed for pumping petroleum, chemical & boiler feed water additives in accurate, predetermined quantities. Capacity table, typical applications with schematic diagrams included.

27 Nuclear Reactor Simulator. Built around an analog computer this nuclear reactor simulator assembly provides graphic demonstration of nuclear reactor kinetics. Aids checking & study of actual reactor instrumentation systems. 4-page folder gives many other details. Leeds & Northrup Co.

28 Photoelectric Analyzer. A new instrument for automatic analysis of process gas & liquid streams is announced by Manufacturers Engineering & Equipment Corp. The model III photoelectric analyzer is self-monitoring, periodically checking & resetting itself to compensate for error. Automatic recording of gases or vapors in air, down to a few p.p.m. is said to be one of the outstanding uses for this device.

29 Actuator. From Weighing Components, Inc. loose-leaf binder insert on a new electro-hydraulic actuator for fast, precise positioning of butterfly & plug valves, & other large masses. Features infinite resolution potentiometer builtin switches, 400 cycle dither circuit for optimum sensitivity.

30 Electro-Pneumatic Control. Called Speedomax H this current-adjusting type electro-pneumatic control is described in illustrated binder insert giving full description with complete line drawings & photographs. Specifications & standard ranges tabulated.

31 Submersible Booster Pump. Vertiline pump embodies refinements such as oversize shaft, longer bearings with protective caps, perihedral impeller seals, & others. Models from 5 to 150 h.p. with heads 50 to 500 ft. & capacities 100 to 4,000 gal./min. Layne & Bowler Pump Co.

32 Thermocouples. Announced by Conax Corp. an exclusive pressure sealing spring loaded thermocouple. Insures positive contact for high thermal conductivity. Useful in checking temperatures of bearings, surfaces & injection molding machines-⅛-in. two wire pyod construction insures fast response.

33 Airfoil Fans. Chicago Blower Corp. has a heavy-duty fan type L which incorporates two entirely new aero-dynamic design features. Streamline contours given to all surfaces contacting the air stream. Exclusive aerodynamic blade design. Wheels 2, 4, 6 & 8 blades available. Eight models with fourteen types of wheels from 12 to 72 in. diam. Bulletin.

34 Solenoid Valve. A packless 3 way solenoid valve operated by a new principle is introduced by Automatic Switch Co. Three operating parts—two hycar diaphragms & one stainless steel solenoid core. Seat regrinding & lapping eliminated. Automatic Switch Co.

35 Concentrating Clarifiers. A new series of these units utilizing an ingenious recycling system which reuses waste water announced by Centrico, Inc. Primarily used for continuous solids concentration where one liquid containing solids is to be clarified or where it is desired to concentrate solids in a small portion of a liquid.

(Continued on page 67)

CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on admissions.

These names are listed in accordance with Article III, Section 8, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members will receive careful consideration if received before February 15, 1956, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

Member

Bowles, Vernon O., *Rye, N. Y.*
Braunlich, Richard H., *West Chester, Pa.*
Cline, W. E., *Charleston, W. Va.*
Hill, Orville F., *Richland, Wash.*
Hurd, Frank W., *New York, N. Y.*
Jorquera, G. A., *Baltimore, Md.*
Kalcevic, Victor, *Midland, Mich.*
Kelly, Ralph L., Jr., *So. Charleston, W. Va.*
Martinez, Remigio, *Rosita, Coah., Mexico*
Muehlman, R. L., *Belle, W. Va.*
Neumann, William Michael, *New York, N. Y.*
Padgett, A. R., *Baytown, Tex.*
Rockwood, William R., *Texas City, Tex.*
Sanders, J. C., Jr., *Lake Jackson, Tex.*
Seth, D. S., *Painesville, Ohio*
Stusiak, Michael, *Richmond, Calif.*
Toms, William P., *Wilmington, Del.*
Wacks, Norman, *Orange, Tex.*
Warren, James H., *Richland, Wash.*
Webster, F. X., *Stanford, Calif.*
Weiner, Harry S., *Pasadena, Tex.*
Wilson, J. S., Jr., *Lake Jackson, Tex.*
Wolf, Robert R., *Midland, Mich.*
Harris, Marvin S., *Atlanta, Ga.*
Herrera, Antonio R., *Del Rio, Tex.*
Holt, H. Wade, *Tulsa, Okla.*
Holtz, John W., Jr., *Baltimore, Md.*
Jaglom, Jacob, *New York, N. Y.*
Kahn, Rolf, *Livingston, N. J.*
Kelly, James P., *So. Charleston, W. Va.*
King, Charles L., *Charleston, W. Va.*
Kress, Rene Floyd, *Media, Pa.*
Leithiser, R. S., *So. Charleston, W. Va.*
Lowery, A. J., Jr., *Overland, Mo.*
Lyndall, Frank S., Jr., *Wilmington, Del.*
Mac Artor, Frank L., *Terre Haute, Ind.*
Masterton, Bruce, *Denver, Colo.*
McHenry, Keith W., Jr., *Whiting, Ind.*
Melgren, Willis H., *Manhattan, Kan.*
Moore, David G., *Pittsburgh, Pa.*
Nichols, L. R., Jr., *Paulsboro, N. J.*
Nored, Donald L., *Cleveland, Ohio*
Owens, James B., *Atlanta, Ga.*
Packard, Robert, *Portsmouth, Ohio*
Peacock, A. J., Jr., *Kingsport, Tenn.*
Petterson, David L., *Wollaston, Mass.*
Poling, Edgar L., *Waynesboro, Va.*
Poole, R. E., *Hopewell, Va.*
Prados, John W., *Knoxville, Tenn.*
Riddle, Jack H., *El Paso, Tex.*
Rollbuhler, R. James, *Elyria, Ohio*
Sachs, Herbert B., *Cincinnati, Ohio*
Shick, L. W., *Clinton, Ont., Can.*
Sieraski, Richard James, *Wilmington, Del.*
Simmons, Thomas S., *Detroit, Mich.*
Snedeker, Robert A., *Parlin, N. J.*
Solomon, Yale, *Pittsburgh, Pa.*
Somer, Tarik G., *New Castle, Del.*
Sonnett, William M., *Pittsburgh, Pa.*
Sorenson, Dale H., *Longview, Wash.*
Sullins, John K., *Kingsport, Tenn.*
Taska, I. J., *Freeport, Tex.*
Tomlinson, Arthur Richard, *Upland, Pa.*
Tuley, John Louis, *Springfield, Mass.*
Warren, James C., *Media, Pa.*
Webber, Robert T., *Monsanto, Ill.*
Wett, Theodore W., *Mt. Prospect, Ill.*
Wilson, Edward L., Jr., *Baytown, Tex.*
Van Winkle, Jon, *White Plains, N. Y.*
Woodham, J. F., *Beaumont, Tex.*
Yantz, Robert C., *Kingsport, Tenn.*

Associate

Allison, Kenneth W., *Birmingham, Mich.*
Almlof, John W., *Chicago, Ill.*
Applegate, Robert S., *Lewiston, N. Y.*
Armstrong, M. C., *Hebron, Ohio*
Barnes, James I., *Wenonah, N. J.*
Bathiany, Robert O., *Longview, Wash.*
Blanchard, T. R., *Waterbury, Conn.*
Bovard, James A., *Hoboken, N. J.*
Bradley, Paul L., *Chicago, Ill.*
Brennan, Peter John, *Stamford, Conn.*
Bruce, H. William, *Newton Highlands, Mass.*
Byam, John D., *Orange, Tex.*
Charlian, Jonathan E., *Cambridge, Mass.*
Craig, Francis J., *Prospect Park, Pa.*
Cross, Braxton W., *Blountville, Tenn.*
Di Vito, Alfred L., *Detroit, Mich.*
Famularo, Jack J., *Springfield, Mass.*
Fantini, Ralph, *Philadelphia, Pa.*
Ferrise, Louis J., *Elizabeth, N. J.*
Fish, John W., Jr., *New York, N. Y.*
Fisken, Alexander M., *Tacoma, Wash.*
Forrest, David B., *Vancouver, B.C., Can.*
Forster, Howard A., *Phila., Pa.*
Fry, Otto E., *Baton Rouge, La.*
Garrett, David, *Brooklyn, N. Y.*
Gillett, Richard B., *Augusta, Ga.*

Affiliate

Corporales, George W., *Santa Fe Springs, Calif.*
Wheeler, Carl L., *Velasco, Tex.*

materials-

45 Anhydrous H_2O_2. Commercial development of hydrogen peroxide solutions in concentration range between 90 & virtually 100% H_2O_2 content is announced by Becco Chemical Div., of Food Machinery and Chemical Corp. Bulletin No. 70 & related patent offer additional information. Other technical data not presently available.

46 Di-Isodecyl Phthalate Plasticizer. Due to favorable testing & increased interest Ohio-Apex Div. of Food Machinery and Chemical Corp. is now producing this material commercially. Said to show less volatile loss than other plasticizers.

47 Isosebacic Acid. This new synthetic organic chemical was developed by U. S. Industrial Chemicals Co. It is a mixture of C-10 aliphatic dicarboxylic acids. A promising intermediate for plasticizers, ester lubricants, polyamids & others.

48 Organic Chemicals Handbook. From Carbide and Carbon Chemicals Co. "Physical Properties of Synthetic Organic Chemicals," features 32 new products. Lists latest data on over 350 organic chemicals.

DEVELOPMENTS OF THE MONTH *(Cont.)*

105 Polyisobutylene Dispersions. Stable aqueous dispersion, over 50% solids, of Enjay Co's. Vistanex, is a new product offered for the first time in fully commercial quantities by Miller-Stephenson Chemical Co., Inc.

Dispersion 108 is suggested for use in binders, adhesives, protective coatings, sealing compounds; its chemical inertness, resistance to aging and to water absorption are said to promise wide usefulness in many fields. Films formed from Dispersion 108 are permanently tacky, retain flexibility to low temperatures. New technical data sheet lists properties, specifications, package data and suggested uses.

49 Chemicals. Amongst the new chemicals produced in commercial quantities by Arapahoe Chemicals, Inc., are cyclopentane, cyclopentyl propionic acid, succinyl choline chloride, cupferron, potassium Metaperiodate & thioacetamide.

50 Tantalum. The use of this material in sulfuric acid is desirable because of its high resistance to corrosion by sulfuric in all concentrations. It is inert to dilute acid at boiling temperatures. Resists attack to concentrated acid at low temperatures below 145° C. Fansteel Metallurgical Corp.

51 Plaskon Polyester Resins. Three new premix Plaskon polyester resins designed for rapid molding of intricate parts with varying wall thicknesses are being introduced by Barrett Div. of Allied Chemical & Dye Corp. Detailed information available.

52 Lithium Carbonate. Technical bulletin on this material available from American

(Continued on page 69)

materials-(Cont.)

Potash & Chemical Corp. Used in porcelain enamel manufacture, glass & ceramic production, petroleum & other industries. Bulletin gives information on chemical analysis, solubility in water, uses, etc.

53 Silicone Guide. A new 1956 reference guide to Dow Corning Corp. silicone products available. Describes almost 150 of most generally used, 18 of which were recently introduced. Grouped by physical form, indexed by usage, gives product descriptions in condensed form.

54 HET Anhydride. New with Hooker Electrochemical Co. is HET anhydride. Use is as hardener or curing agent for liquid epoxy resins. Has two properties heretofore unavailable together—fire resistance & high temperature strength. A.S.T.M. heat distortion values approach 200° C.

55 Epsilon Caprolactam. National Aniline Div. technical bulletin I-14 contains fundamental data on this material not heretofore available commercially. Complete listing of chemical & physical properties, basic reactivity & uses.

56 Organo-Silicone Compounds. Linde Air Products Co. have introduced six new organo-silicone compounds with unusual lubricating and solubility properties. Designated X-520 to X-527 inclusive chemicals are offered for development purposes & also in commercial quantities. Said to possess many new properties. Data sheet available.

57 Gasoline Antioxidant. Koppers Co., Inc. offers a technical bulletin on DBPC-gasoline antioxidant which describes in detail result of experiments & tests with antioxidant additive for gasoline—2,6-di-tertiary-butyl-para-cresol. Designed for the refiner who seeks high quality improvement plus lower treating costs.

58 Urea & Melamine Resins. A booklet describing Plaskon urea & melamine coating resins is available from Barrett Div., Allied Chemical & Dye Corp. Presents complete properties of these resins together with recommendations for use.

59 Intermediates. Two new intermediate silicone rubber products available from Dow Corning Corp. One polymer is identified as Silastic 430 gum. The other Silastic 432 base is reinforced gum or master batch. Designed to exhibit minimum shrinkage during vulcanization.

60 Chlorinated Polymer. Available from Beaumont, Heller & Sperling, Inc. a new chlorinated polymer which combines good mechanical strength, high temperature & chemical resistance, good dimensional stability & free machinability.

61 Iron Surfaced Floors. Material called Metal-Flex forms a nonporous, dust-free, & corrosion resistant floor. Withstands rapid changes in temperature & is oil & grease resistant. May be applied to new concrete as soon as water disappears. Flexrock Co.

(Continued on page 71)

bulletins

70 Process Equipment. Struthers Wells Corp. have a 20-page brochure on process equipment including dryers-kilns, heat exchangers, evaporators, of stainless steel fabrication. Well illustrated, book contains description of each unit, features, etc.

71 Lubrication Bulletin. "Diesel and Gas Engine Lubricating and Fuel Oil Maintenance," a bulletin produced by Hilliard Corp. divides oil contaminants into two groups with recommendations for lubricating oil filters either by-pass or full flow. Tabulated chart based on engine horsepower lists proper tube & size of oil filter equipment needed.

72 Nitrogen Generators. Binder insert bulletin from C. M. Kemp Mfg. Co. gives detailed flow diagram & complete operating explanation. Shows detailed data chart specifying utility requirements for nine models. Graphs show exact analysis of nitrogen delivered with various air-fuel ratios.

73 Blower. A two-color folder from Standard Corp. gives engineering details & technical specifications of a product for handling air or other gases under pressure or vacuum. Called Standardaire it is an axial-flow, positive-displacement unit. Without touching two rotors operate with clearance of a few thousandths of an inch. Eliminates friction wear & internal lubrication.

74 Bulk Handling. Tote System, Inc. describes bulk handling systems for materials ranging from soluble coffee to silicones. Of special interest to those with problems of inplant bulk storage. Illustrated folder shows installations, cites advantages.

75 Stainless Steel Handbook. Crucible Steel Co. of America makes available a handbook of stainless steel. Sections on forming, machining, cutting, joining, heat treating, finishing. Also much reference data on weights, gauges, etc.

76 Aluminum Pipe. For conveying everything from air to acid, aluminum pipe from Aluminum Co. of America is shown in booklet. Presents characteristics & advantages of products in major fields of application. Specifications provided with description of appropriate fittings & installed on methods.

77 PVC Pipe Fittings & Flanges. Booklet from Tube Turns Plastics, Inc. discusses industrial applications of PVC pipe, gives complete specifications for fittings & flanges in both normal & high impact grades. It is inert, non-toxic, easy to install & disassemble & light weight.

78 Conveyor Belt Carriers. Illustrated bulletin on standard belt conveyor carriers & trippers. Also special carrier units with accessories. Issued by Stephens-Adamson Mfg. Co. Addition to line is a long center roll carrier with 35° to 45° slope end rolls for increased carrying capacity on light materials such as grain & wood chips.

(Continued on page 72)

bulletins-(Cont.)

79 Dust Collectors. Elimination of dust nuisance at source is subject of a 4-page illustrated bulletin from Omega Machine Co. Contains installation & dimension diagrams. Advantages include no need for long ducts or pipes & other features.

80 Reclaiming Still. Designed to eliminate impurities in solvents & allow their re-use a reclaiming still developed by Struthers Wells Corp. Constructed of carbon steel it is available in stainless alloys & non-ferrous construction. Design based on standard parts permits quick shipment.

81 Rotocycle Meters. Rockwell Mfg. Co. has issued an 8-page bulletin on their line of all-bronze Rotocycle meters including 2, 3 & 4 in. bulk-type models & 2 & 3 in. tank truck models. Flow rates 20 to 500 gal./min. Used for metering alcohols, brines, other liquids.

82 Laboratory Glassware. A loose-leaf binder supplement to their catalog is available from Ace Glass Inc. Contains outstanding items added to line.

83 Protective Coatings. Two new illustrated catalogs one for the industrial construction field, the other for plant maintenance engineers issued by Amercoat Corp. to describe their method of corrosion control. Outlines various corrosion-resistant coatings systems manufactured.

84 Dehumidifiers. A profusely illustrated catalog describes the central type sprayed coal dehumidifiers available from American Blower Corp. Featured is a 10-page section on application data. Also discussed are water dilution, high humidification, etc.

85 Steel Tubing. Those associated with application of tubular products in processing will find a folder from Babcock & Wilcox Co. of interest. Contains complete listing of types of tubing & tubular products made, also boiler & mechanical tubing.

86 Conversion Tables. From Wheelco Instruments Div. of Barber-Colman Co. a bulletin on "Standard Conversion Tables." Gives thermocouple temperature-millivolt equivalents. Temperatures expressed in International Scale of 1948. Electromotive force expressed in absolute units.

87 Processing Plants & Equipment. Catalog from Blaw-Knox Co. illustrates equipment plus complete plants for the chemical & food processing industries. Company is prepared to engineer, construct & put into operation process plants. Also builds stainless steel heavy process equipment.

88 Activated Charcoal. Barnebey-Cheney Co. have issued a technical bulletin on adsorptive characteristics of activated charcoal to distilling processes. Outlines & discusses recovery of large amounts of alcohol lost by evaporation in aging warehouses & loss recovery at bottling machines.

89 Chain Conveyors. Economical conveying of bulk chemicals is the subject of a

bulletin from Buhler Bros., Inc. Advantages claimed for system include sanitary working, free from dust; saving of space & maintenance time; careful handling making over-filling impossible, & others.

90 Temperature Control. A remote indicating temperature control instrument actuated by a liquid-filled bulb & bellows for positive action, it has a range of 100 to 700° F. Differential adjustable to between 1 & 4% of scale range. Fenwal, Inc.

91 Chlorinator. Fischer & Porter have issued a chlorinator catalog featuring the 1050A for purifying water supplies, treating sewage & industrial wastes & control of slime. Multi-colored flow diagram shows how chlorine gas & water are kept separate until arrival at ejector system.

92 Transformers. A well illustrated 32-page catalog from General Electric Co. covers their control transformers. Includes standard & special types. Contains ratings, dimensions, product features. Special section shows panel & machine tool voltage regulation curves for selection.

93 Centrifugal Pumps. A bulletin from Goulds Pumps, Inc. covers centrifugal pumps designed to handle corrosive liquids in process & other industries. Details materials of construction, standardization of parts, range of capacities & heads, adjustment, pipe connections, etc.

94 Barometric Condensers. Disc-flow & ejector-jet type barometric condensers are the subject of a bulletin from Ingersoll-Rand. Units said to be highly efficient & are available in sizes to 120 in. diam. & handle to 12,000 gal. of cooling water per minute.

95 Ni-Vee Bronzes. International Nickel Co., Inc. has available a 28-page brochure on the engineering properties & applications of Ni-Vee bronzes. Five basic types. Ni-Vee alloys contain 5% each of nickel & tin with varying lead contents. Recommended for constructional, bearing & pressure castings. Explains cross-over applications.

96 Products Handbook. From Johns-Manville a 52-page book featuring eleven lines of their products for industry such as insulation & refractory products; Transite asbestos-cement pipe; packings & gaskets; Celite Diatomite filter aids & mineral fillers & others. Essential engineering data plus product descriptions & other related information, included.

97 Controlled Volume Pumps. Milton Roy Co. describes its line of controlled volume pumps for "downhill" metering of liquids & gases in a new bulletin detailing the operation & application of the new Minus Delta P group. Lists specifications, capacities & features.

98 Pump Design Reference Card. A movable insert in a reference card from Peerless Pump Div., Food Machinery and Chemical Corp. demonstrates how parts in their chemical process pumps may be easily interchanged. Also carries information on specifications & shows head & capacity curves.

HOUSTON ENGINEERS, SCIENTISTS UNITE IN NEW CENTER

Typical of the rapid growth in science and engineering in Houston is the planned new Technical and Scientific Center.

Sponsored by the Houston Engineers Club, Houston's proposed new Technical and Scientific Center will bring together for the first time in the Southwest the scientists and engineers of a highly diversified range of technical fields in a common meeting place. Main aim: To afford an unparalleled opportunity for the exchange of ideas between the more than 9000 members of the 35 technical societies represented in Houston.

In an area where science and industry continue to grow by leaps and bounds, where one-fourth of all professional engineers in Texas live, a common Center is expected to establish the city as the engineering center of the Southwest.

Planned to cost $300,000, the remodeling job on the facilities of the present Engineer's Club will furnish a spacious and practical central meeting place and headquarters with lecture halls, conference rooms, reading and reference rooms, secretarial services, employment services, dining facilities, space for technical and scientific displays, headquarters space for the various technical societies, mailing and records storing, club offices, and above all a spot for general getting-together between all engineers.

As in any other field of endeavor, in unity there is strength—in a unity that is fully cognizant of the needs of individuality that is. A center provides just this kind of unity for engineers and scientists.

Already the $300,000 bond issue, which has been issued to finance the work, is half subscribed by Engineer's Club members. But purchase of the bonds is not limited to members. Club officials feel certain that industry, aware of the importance of the Center to the growth of science and engineering in the area, will subscribe the rest of the needed funds for this progressive project.

The Oak Ridge School of Reactor Technology is now accepting applications for enrollment in the 1956-57 session. The School is a division of the Oak Ridge National Laboratory, which is operated by Union Carbide and Carbon Corporation for the U. S. Atomic Energy Commission. Industrial organizations and government agencies are invited to sponsor people from their technical staffs for this 50 week training program in nuclear reactor engineering. The deadline for receipt of applications is March 12, 1956; the session begins on September 10, 1956. Further information and application forms may be obtained from the Director, Oak Ridge School of Reactor Technology, Oak Ridge National Laboratory, P. O. Box P, Oak Ridge, Tennessee. □

Concerned with Nuclear engineering, a new publication in the Chemical Engineering Problems series, compiled by the Chemical Engineering Education Projects Committee and published by the A.I.Ch.E., is now available, presents a series of selected problems in nuclear engineering.

Contributed by Stuart McLain, Argonne National Labs, and R. E. Aven, Oak Ridge, the nuclear problems are available from A.I.Ch.E. headquarters in New York, cost: 25 cents. □

Refinery Engineering Co., Tulsa, Okla., will become a wholly-owned subsidiary of Vitro Corp. of America. Refinery Engineering is a well-known company in the field of engineering and constructing oil refineries, petroleum by-product chemical plants, and other similar types of engineering construction. □

The emission microscope in the picture is one of only six in the world, four of these being homemade. The other two, including the one above, have been built by Philips Laboratories, Eindhoven, Netherlands, for the U. S. Naval Research Laboratories, whose L. S. Birks (center) watches a demonstration of the instrument by G. Boas, Philips Laboratories. R. D. Heidenreich, Bell Telephone Laboratories (left) also observes the demonstration given in the offices of North American Philips Co., Mount Vernon, N. Y., U. S. representative of Philips. □

ENGINEERS IN HIGH SCHOOL TEACHING

Requirements for engineers who teach in New York City High Schools are published as indication of the many rewards available.

Attention, long centered on college and university teaching, is now beginning to shift to the secondary schools. Many educators and industrialists are now showing considerable concern over the state of science teaching in the secondary schools. Certainly if a boy is not interested in science in high school he is unlikely to study science or engineering in college, and all our efforts to improve engineering education in college will be quite meaningless.

Mindful of the growing interest on the part of industry and the educators, New York City's Board of Education has published its requirements for an engineer to teach in its high schools. *CEP* finds these requirements highly informative, considerably encouraging. Basic requirement is graduation from a four year engineering school. After that the city asks at least three years experience as a practicing engineer. There are definite requirements in the area of education courses, but these can be taken within three years following the teaching examination.

For the engineer who wants to teach in this highly important area, New York gives a starting salary of $4888 to a regular teacher with five years of engineering experience, $5288 if he holds a master's degree. Increments bring the top salary to $7200 ($7600 with the master's) over a period of years. In addition there are numerous opportunities for advancement to higher paying positions, and many fringe benefits including tenure, pension, health benefits, sick leave, insurance after a number of years service, good vacations, etc.

And in all, New York's teachers do not fare badly. For the man with the desire to teach, the rewards are good, and there is the satisfaction of doing a job he likes, one that is vital to the nation.

Free assistance, and the lending of special nuclear material, will continue to be the policy of AEC as far as nonprofit educational and medical institutions are concerned. Commercial or industrial licenses of AEC materials and know-how will pay full costs for both materials and services, in accordance with the pricing policy announced last January. ☐

The successful development of an aluminum die-cast engine block weighing only 43 pounds trimmed compared to 175 pounds for the same engine block in grey iron, has been accomplished by the Doehler-Jarvis Division of National Lead Company working in conjunction with Kaiser Aluminum and Chemical Corp. ☐

New nuclear engineering and engineering science programs at New York University are built around a sub-critical reactor. Beginning during the just ending fall semester, the new nuclear engineering program is confined to the graduate level leading to a degree of master of nuclear engineering, and is designed to teach the engineer to design, construct, and supervise the operation of devices and processes involving nuclear reactions.

The sub-critical reactor cannot maintain a chain reaction and is therefore safe for classroom use. Costing only a few thousand dollars the reactor is economical and accurate enough for student experiments. With this reactor the student can be trained in the physics of the chain reaction, reactor theory, and diffusion theory.

The engineering science program, an undergraduate curriculum, leads to the bachelor's degree and is primarily designed to lead to a specialization in nuclear engineering. ☐

Behind the formation of a new salt company, Chemical Salt Production Co., Great Salt Lake, Utah, is the growth of two leading chemical companies: Hooker Electrochemical and Pennsylvania Salt Mfg. Co. Both companies use salt as the basic raw material of their west coast plants, both companies see a shortage in the future, hence they have joined to form the jointly-owned subsidiary, Chemical Salt Production Co.

Construction of the plant at Great Salt Lake is already underway. ☐

INDUSTRIAL NEWS

Syntron Co., Homer City, Pa., will operate as a subsidiary of Link-Belt Co., Chicago, when a planned merger goes through. Syntron's line of electromagnetic and electronic equipment, including feeders, rectifiers, portable power tools, shaft seals, and other equipment for the movement of materials, will fit well into the production scheme of Link-Belt. □

An open competitive examination for all branches of engineering in grades GS-5 through GS-9 has been announced by the U. S. Civil Service Commission. □

A new Engineering Department has been formed in Pittsburgh Coke & Chemical Co., Pittsburgh, Pa., to serve the company's five operating divisions that comprise its chemical group. □

Concerned over what it considers a dangerous cutback in science teaching at the secondary level, Shell Companies Foundation, New York, N. Y., is undertaking a broad program of recognition fellowships for high school teachers of science and mathematics.

Shell will underwrite summer seminars at Stanford and Cornell for 60 teachers yearly, will give travel allowances, all tuition and fees, living expenses, and $500 in cash to make up for the loss of potential summer earnings. □

Canada's aluminum production will go up some 30% when a planned $200 million aluminum and hydroelectric project goes on stream. Plant is being built by a Canadian subsidiary of British Aluminum Co., Ltd., at a cost of $130 million, Quebec Hydroelectric is undertaking the $70 million hydroelectric development required to power the plant. □

Having trouble with market research problems in Europe? If so, International Researchers Associated, a new division of International Processes, Inc., has been set up to offer aid in this problem.

In addition to market research through its trained engineers and scientists in many countries, the new division will obtain qualified distributors for you, undertake special assignments, and conduct technical and industrial research help. □

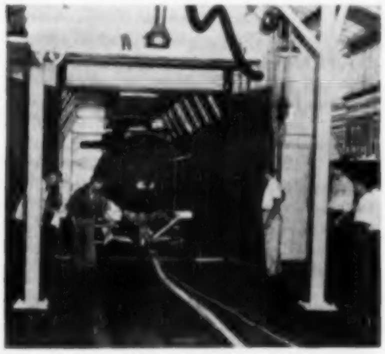
Truland Chemical & Engineering Co., Union, N. J., has merged with the Trubek laboratories, East Rutherford, N. J. Truland will continue under the new name of Truland Chemical Co. □

New sulfuric acid plant is under construction by Du Pont some 20 miles from Cincinnati.

The unit, known as the Fort Hill Works, will be operated by the Grasselli Chemicals Department of Du Pont, will replace a plant now operated by the Department at Lockland, near Cincinnati. □

A 600 bbl./day Unifining unit has gone on stream at Aurora Gasoline Co.'s Muskegon, Mich., refinery. Designed by Universal Oil Products, the new unit will process cracked distillates and naphthas to produce part of the feed stock for a UOP platforming unit. □

The growing demand for nuclear instruments is behind an extensive expansion program underway at NRD Instrument Co., St. Louis. □



When a 4,050 gallon highway tank trailer began hauling sulfonic acid recently, it marked a major advance toward greater long-range economy in the transportation of corrosive chemicals. The step was made possible by coating the Trailmobile trailer on the inside with a new high-temperature resistant, chemically inert fluorocarbon plastic coating developed by M. W. Kellogg, baking the entire tank (above) in one of the largest furnaces ever built for experimental coating use. □

Large new deposits of titanium ore have been discovered by National Lead Company—one in New York State, and the other in Norway. Both are readily available, are near the company's present installations, will help fill the growing demands for titanium throughout industry. The Norwegian deposit may well be one of the largest in the world when its extent has been finally determined. □

The growing market for reinforced plastics was demonstrated at the recent national conference of the American Trucking Association in Washington, D. C., by a display of truck trailers and tanks fabricated from Celanese polyester resins. On show were a streamlined chemical tank carrier, a high cube trailer, and a milk transport trailer, all of reinforced polyester resins. □

FUTURE MEETINGS and Symposia of the Institute

Los Angeles National Meeting, February 26-29. Complete program and list of activities appears on pages 42 to 46 of this issue.

NEW ORLEANS

May 6-9, 1956. Roosevelt Hotel.

TECHNICAL PROGRAM CHAIRMAN: H. E. O'Connell, Ethyl Corp., Box 341, Baton Rouge, La.

Effective Industrial Financial Aid to Colleges

CHAIRMAN: K. O. Beatty, No. Caroline State Coll., Raleigh.

A Sunday afternoon panel discussion to try to resolve means of implementing our growing needs for trained personnel.

Fundamental Mechanism in Boiling, Cavitation and Condensation

CHAIRMAN: R. R. Hughes, Shell Dev. Co., Emeryville, Calif.

To cover the large middle ground between studies of nucleation kinetics and empirical studies of over-all boiling and condensation heat transfer rates.

Foreign Chemical Developments & their Effect on U. S. Chemical Industry

CHAIRMAN: C. W. Humphreys, Shell Chem. Corp. 50 W. 50th St., New York, N. Y.

The effect of foreign competition, both commercial and technological, upon the U. S. chemical industry.

Liquid Metals

CHAIRMAN: C. F. Bonilla, Dept. of Chem. Eng., Columbia U., N. Y. 17, N. Y.

The fields in which liquid metals have merit and the methods of utilizing them, with particular emphasis on sodium.

Deadline—January 6, 1956

MEETINGS **SYMPOSIA**

■ PITTSBURGH, PA.

Sept. 9-12, 1956. Wm. Penn Hotel.

TECHNICAL PROGRAM CHAIRMAN: Carl C. Monrad, Carnegie Institute of Technology, Pittsburgh, Pa.

Mixing

CHAIRMAN: J. H. Rushton, Dept. of Chem. Eng., Purdue U., Lafayette, Ind.

Distillation Computation Methods

CHAIRMAN: Wayne C. Edmister, California Res. Corp., Richmond, Calif.

Operations Research

CHAIRMAN: George D. Creelman, M. A. Hanna Co., 1300 Leader Bldg., Cleveland 14, Ohio.

Case studies showing a wide variety of methods and techniques in applications of operations research in chemical engineering.

Explosions in Chemical Engineering

CHAIRMAN: G. H. Damon, 366 Ashland Ave., Pittsburgh 28, Pa.

Symposium on gas and dust explosions.

Unit Operations in Nuclear Engineering

CHAIRMAN: George Sege, 1915 Harris Ave., Richland, Wash.

General Papers

Deadline—May 11, 1956

Nuclear Engineering Division Congress and Atomic Exposition at Philadelphia, Pa. September 28 to October 5.

Theme of Congress: The Fuel Cycle.

■ TERRE HAUTE, IND.

April 21, 1956. Rose Polytechnic Institute.

1-day meeting on Bio-Engineering sponsored by the Terre Haute Section, A.I.Ch.E.

CHAIRMEN: C. W. Smith and R. A. Shurter. Contact Mr. Shurter at Commercial Solvents Corp., Terre Haute, Ind.

■ ANNUAL—BOSTON, MASS.

Dec. 9-12, 1956. Hotel Statler.

TECHNICAL PROGRAM CHAIRMAN: W. C. Rousseau, Badger Mfg. Co., 230 Bent St., Cambridge 41, Mass.

Extraction of Hydrocarbons for Chemical Use from Pipeline Gases

CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

Filtration

CHAIRMAN: F. M. Tiller, U. of Houston, Cullen Boulevard, Houston 4, Tex.

The flow of liquids through compressible media, with experimental and theoretical papers.

Low Temperature Separations

CHAIRMAN: Dr. Clyde McKinley, Air Products, Inc., Allentown, Pa.

General Session: "Obsolescence" of Chemical Engineers.

General Session: Pertaining to Sales Engineers.

Deadline—August 9, 1956

UNSCHEDULED SYMPOSIA

Laboratory and Pilot Plant Techniques

CHAIRMAN: Thomas S. Leary, Calco Chemical Div., American Cyanamid Co., Bound Brook, N. J.

Centrifugation

CHAIRMAN: James O. Maloney, Dept. of Chem. Eng., U. of Kansas, Lawrence, Kan.

Fluidization of Solids

CHAIRMAN: E. R. Gilliland, Chem. Eng. Dept., M.I.T., 77 Massachusetts Ave., Cambridge 39, Mass.

Drying

CHAIRMAN: Ralph E. Peck, Chem. Eng. Dept., Illinois Institute, 33rd Federal, Chicago 16, Ill.

Cost of Unit Operations

CHAIRMAN: John Happel, Chem. Eng. Dept., New York U., University Heights 53, N. Y.

Size Reduction

CHAIRMAN: Edgar L. Piret, Chem. Eng. Dept., U. of Minnesota, Minneapolis 14, Minn.

Dry Classification of Solids

No Chairman Assigned.

AUTHOR INFORMATION

Note: The Author Information column will appear quarterly in the January, April, July and October issues.

Submitting Papers

Members and nonmembers of the A.I.Ch.E. who wish to present papers at scheduled meetings of the Institute should follow the following procedure.

First, write to the Secretary of the A.I.Ch.E., Mr. F. J. Van Antwerpen, American Institute of Chemical Engineers, 25 West 45th Street, New York, requesting three copies of the form "Proposal to Present a Paper Before the American Institute of Chemical Engineers." Complete these forms and send one copy to the Technical Program Chairman of the meeting for which the paper is intended, one copy to the Assistant Chairman of the A.I.Ch.E., Program Committee, address at the bottom of this page, and one copy to the Editor of Chemical Engineering Progress, Mr. J. B. Mellecker, 25 West 45th Street, New York.

If you wish to present the paper at a particular symposium, request 4 copies of the proposal sending a copy to the Chairman of the symposium.

Before Writing the Paper

Before beginning to write your paper you should obtain from the meeting Chairman, or from the office of the Secretary of the A.I.Ch.E. at 25 West 45th Street, New York, a copy of the A.I.Ch.E. Guide which covers the essentials required for submission of papers to the A.I.Ch.E. or its magazines.

Copies of Manuscript

Five copies of each manuscript must be prepared. For meetings, one should be sent to the Chairman of the symposium, and one to the Technical Program Chairman of the meeting at which the symposium is scheduled. If no symposium is involved, the two copies should be sent to the Technical Program Chairman. The three other copies should be sent to J. B. Mellecker, Editor of C.E.P., 25 W. 45, N. Y. 36, N. Y. All manuscripts submitted to the A.I.Ch.E. Editor are automatically considered for C.E.P., the A.I.Ch.E. Journal, and the Symposium Series. Presentation at a meeting is no guarantee that manuscripts will be accepted.

Chairman, A.I.Ch.E. Program Committee, L. J. Coulthurst, Foster Wheeler Corp., 165 Broadway, New York 6, N. Y.

Assistant Chairman, E. R. Smoley, The Lummus Co., 385 Madison Ave., New York 17, N. Y.

Anyone need 7000° F. temperature from a unit costing $400? If you do, thermodynamic engineers of Convair Division, General Dynamics Corp., have devised efficient solar furnaces to do the job at that price. How? Converting war-surplus anti-aircraft searchlights.

Three 60-inch searchlights, costing only $400 each, were acquired to augment Convair's 120-inch solar furnace already in operation for a year in the high-temperature testing of metals, ceramics and other materials.

The polished metal surfaces of the searchlight mirrors concentrate sun rays into a spot smaller than a dime. At this point the 7000° plus temperature can be easily produced. By comparison, an oxyacetylene torch develops a temperature of about 5800° F.

Only minor modifications were necessary to convert the searchlights. Engineers merely removed the arc lighting mechanisms and glass covers, installed a drill specimen holder, attached adjustment handles to move the test samples into and out of the focal point. □

The complete collection of technical papers from the Government Synthetic (Copolymer) Rubber Program is now available to any interested engineer from the Office of Technical Services, Dept. of Commerce, Wash., D. C., price $5 the four-volume set. □

New types of encapsulated transformers which will enable designers to specify the exact degree of encapsulation required without having to pay for unnecessary protective extremes, are now on the market from General Electric's Specialty Transformer Dept. Some models designed specifically for industry, will give protection against grease, oil, and corrosive atmosphere. □

A tour of the so-called "Chemical Valley" at Sarnia, Ont., will feature the 6th Divisional Conference of the Chemical Engineering Division, The Chemical Institute of Canada, to be held March 5, 6, and 7, 1956, at the Guildwood Inn, Sarnia.

Main theme of the conference will be descriptive material for industrial plants, and prospective authors should contact H. R. Holland, Operational Analyses Dept., Imperial Oil Ltd., Sarnia, Ont. □

An atomic reactor plant that would produce electrical energy as well as fuel-grade plutonium and other valuable isotopes, has been designed by engineers of General Electric. The multiple-purpose reactor would produce 223,000 kilowatts of electrical power. □

Looking for a new job—for yourself or a friend? Chemical engineers who are will find what companies have what openings in their specialties by consulting a new directory called *Engineers' Job Directory* and published by Decision, Inc., Cincinnati, Ohio. For engineers 112 companies are listed. □

To provide engineering, design, development and manufacturing facilities for steam condensers and auxiliaries, heat exchangers, pumps and valves for atomic power generation, C. H. Wheeler Mfg. Co., Philadelphia, Pa., has formed a new Atomic Energy Division. □

Entering a relatively new field, Davison Chemical Co. Division of W. R. Grace & Co. will build a liquid fertilizer plant at Wakarusa, Ind. □

The growth in interest in Fluid Coke is continuing with Bankline Oil Co. awarding a contract to the Fluor Corp., to engineer a 4000 bbl./stream-day Fluid Coking unit for Bankline's Bakersfield, Calif., refinery. □

A 200-ton/day synthetic ammonia plant will be built at Millhaven, Ontario, for Canadian Industries (1954) Ltd. Girdler Corp. of Canada is doing the building, plant will use the Texaco partial oxidation process with residual fuel oil as raw material for synthesis gas production. □

Construction has begun on the Army Package Power Reactor project at the Engineer Research and Development Laboratories, Fort Belvoir, Va. Builder and designer is Alco Products, Inc., Schenectady, N. Y. Plant has been designed so that components of future units can be airlifted to remote sites.

Plant will generate some 2000 kilowatts of electricity for use in normal post operations at Fort Belvoir. □

Modernization and expansion of The Carborundum Co.'s "Monofrax" Refractories plant at Falconer, N. Y., will cost $1.5 million, take five years to complete. □

Construction is underway at Monsanto's Springfield, Mass., Plastics Division plant to triple production capacity of vinyl chloride paste resin. New facilities are expected to go on stream in the second quarter of 1956. □

Natural gas will be principle raw material in a new synthetic nitrogen plant being built at Savannah, Ga., for Southern Nitrogen Co. First of its type in the South Atlantic states, the new plant will cost some $14 million, will produce 250 tons of ammonia/day, is being built by the Girdler Co., Louisville, Ky. □

people

John D. Fennebresque joins Food Machinery and Chemical as vice president and assistant to the president.

Formerly vice president, assistant to the president and a director of Celanese, Fennebresque graduated from Yale in 1939 with a degree in chemical engineering. A director of the Manufacturing Chemists Association, Fennebresque has long been active in public service for the country and the industry.

Kenneth A. Kobe, professor of chemical engineering, Univ. of Texas, has been elected National President of Omega Chi Epsilon, honorary chemical engineering fraternity. The fraternity, embarking on a drive to gain chapters at accredited chemical engineering schools and departments, now has its national headquarters in the Chemical Engineering Bldg., Univ. of Texas, Austin, Tex.

Howard A. Blyth advances to asst. to the general manager, Organic Chemicals Div. at American Cyanamid Co. Blyth joined the company in 1943, having had experience with DuPont and George LaMonte & Son in New Jersey.

Having served as manager of mining and chemical operations for International Minerals & Chemical Corp., **Carl A. Arend** moves to position of general manager, Potash Div. of the company. Arend will locate in the company's Chicago general offices.

Goodrich-Gulf Chemicals, Inc., names **D. L. Matthews** chief engineer to locate in Cleveland.

In his previous position as general manager, Avon Lake, O., Matthews supervised a plastics plant expansion for British Geon, Ltd., an affiliate of B. F. Goodrich Chemical Co.

Ned P. Kimberly named district manager of the Cleveland area for the L.O.F. Glass Fibers Co., Toledo. He will headquarter at the company's office in Cleveland.

John B. Maerker to director of development, Houdry Research and Development Labs, Houdry Process Corp. A licensed professional engineer and member of the Institute, Maerker joined the company as development engineer in 1943. **Frederick R. Walser** succeeds Maerker as section chief.

John W. Church appointed vice-president in charge of research and development of Mastic Tile Corp.

Henry Fleming Payne retires from American Cyanamid Co. to become research professor in charge of instruction and research on organic coatings in the Dept. of Chemical Engineering at the U. of Florida.

Anthony P. Massa joins refinery div. of Bechtel Assoc. in New York as senior engineer. He comes to Bechtel from his position as process engineer with H. K. Ferguson Co., also New York.

George W. Blum to chemical engineering staff of Goodyear Tire & Rubber Co. Goodyear announces also appointment of **Edward O. Hirschbeck** and **Charles E. Wise, Jr.,** as plant operating engineers, chemical engineering pilot plant . . . **William M. Larson** to rubber and plastics compounding section.

Howard Stoertz and **Curtis C. Wallace** recently received patent award checks for improvement in storage batteries from C. F. Norberg, president of the Electric Storage Battery Co. Stoertz is chief metallurgist in the research dept. and is retired from his position as chief chemist in the company.

Richard H. Carroll elected vice-president of Winthrop-Stearns, Inc. He was appointed also as manager of the company's principal plant at Rensselaer, N. Y.

Procter & Gamble announces four chemical engineers as new staff members: **Richard N. Miller** to Drug Products Div. Chemical Development; **Herbert B. Sachs** to Research and Development Dept.; **Mary Susanna Virtue** to Drug Products staff; and **Arlington R. Harman,** Product Research.

Monsanto Chemical Co. appoints **Willis M. Cooper** asst. general manager of Research and Engineering Div. of the company.

H. Edgar Daer joins staff of Esso Research and Engineering Co. He is assigned to the economics division.

L. R. Hunter named asst. manager, plastic product section of the Chemical Div. of Koppers Co., Inc.

Homer Fry takes over as superintendent of production in the Coal Chemicals Div. of Pittsburgh Coke & Chemical Co. to be responsible for the over-all production activities of the division's five plants.

William C. Neumann appointed chemical research engineer in Special Applications Dept. of the Permutit Co., New York.

Frank E. Sullivan to position of chief engineer-industrial process for the De Laval Separator Co.

Lawrence A. Roe appointed minerals beneficiation engineer in Engineering Div. of International Minerals & Chemical Corp.

Glenn A. Nesty, asst. to the vice-president in charge of research at Allied Chemical & Dye Corp. is appointed a vice-president of the company.

B. Bynum Turner, vice-president in charge of research and engineering of Ethyl Corp. elected executive vice-president, a new position in the company.

Walter V. Stearns is chief petroleum engineer of The H. K. Ferguson Co. He is a professional engineer with extensive experience in the field of petroleum refinery design.

Humble Oil & Refining Co. promotes **R. A. Dresselly** to technical specialist. Dresselly will be concerned with optimizing operations at the butadiene unit which Humble recently purchased.

Leonard Smiley appointed manager of technical coordination in the Atomic Energy Div. of Sylvania Electric Products, Inc.

Calvin H. Mohr named asst. to the president of D. R. Sperry & Co., Chicago.

John C. Garver joins U. of Illinois faculty as asst. professor in charge of courses in bioengineering.

Walter Gramm elected chairman of the board of directors of Great Lakes Carbon Corp. Gramm, one of the founders of the company, began his career as a salesman for coal producing companies until 1919 when he joined George Skakel, Sr., in the formation of the first organization to finally become the present Great Lakes Carbon Corp.

people

The Atomic Energy Commission names **Charles D. Luke** technical assistant to help develop health and safety standards for civilian atomic projects. Luke formerly held the position of classification director for atomic information.

Dean George Granger Brown and **Professor Wyeth Allen** of the U. of Michigan College of Engineering are visiting Waseda U. in Tokyo. Their visit is preliminary to the proposed support of programs in industrial engineering by Waseda U. under the auspices of the International Cooperation Administration. It is expected that there will be an exchange of members of the faculty of the two universities during this program so that American management and production techniques will be learned in Japan.

Jack C. Dart and **Dr. Alex G. Oblad** appointed vice presidents of Houdry Process Corp., with Dr. Oblad also being elected to the board of directors. Dart is also a member of the firm's board of directors and general manager of the chemicals division. Dr. Oblad is manager of research and development.

Harry B. McClure, president of Carbide and Carbon Chemicals Co., received honorary membership in the American Institute of Chemists at a dinner meeting January 12, 1956, at the Hotel Commodore, New York. McClure has been concerned during the major portion of his career with the development of new chemicals and new uses for them.

Illinois Institute of Technology names **Joseph C. Boyce,** associate director of Argonne National Laboratory, vice-president of academic affairs and dean of the graduate school.

Harold J. Garber joins Westinghouse Commercial Atomic Power Activities as advisory engineer. He had been professor of chemical engineering at the U. of Tenn. and previously on the staff of the U. of Cincinnati.

H. Seymour Colton is new president of Macco Chemical Co., Cleveland. He has resigned as president of Colton Chemical Co., which he founded in 1943, and which subsequently became a subsidiary of the Air Reduction Co., Inc. He plans to devote approximately two-thirds of his time to Macco, to be available for the remainder as a chemical consultant. At Macco he will enlarge manufacturing facilities and develop a line of new products.

Roger Gilmont, adjunct professor of chemical engineering at Brooklyn Polytechnic Institute appointed vice-president, technical director and a member of the executive committee of the Manostat Corp., New York.

Universal Oil Products Co. elevates top personnel: **David W. Harris,** president of the company for more than 10 years becomes chairman of the board and chief executive officer, and **M. P. Venema** succeeds him as president of the company.

J. William Hinkley elected executive vice-president, Research Corp., a nonprofit foundation to support scientific research in educational and scientific institutions.

Barrett Div., Allied Chemical & Dye Corp., makes three managerial changes: **Maurice H. Bigelow** to newly-created position of director of research; **David E. Cordier** to director, Glendale Plaskon Lab; and **James B. Maguire,** director of development.

Seymour Blechman to executive vice-president, Brooks Rotameter Co. Blechman joins Brooks with over 15 years' experience in field of flow measurement and control. He will take over coordination and guidance of product improvement and expansion programs.

Luther R. Hill joins Arthur G. McKee & Co. as process coordinator of the Petroleum Division. Hill had been president of Process Designs, Inc. and as a registered professional engineer is the holder of a number of patents in petroleum and chemical processing, has contributed many published articles on these subjects.

the chemical engineer in

MARKETING

Norman L. Cooperman named by National Lead Co. as head of technical service in sale of plasticizers and stabilizers for vinyl resin industry.

Among those recently named to field sales force of Elastomers Div., DuPont, as part of expansion of the group's activities are: **A. J. Hawkins, Jr., John R. Galloway, Richard W. Ward** and **D. R. Kuespert.**

Pacific Pumps, Inc., announces opening of a San Francisco office for centrifugal pump sales. **Lee Watts** takes over direction of new headquarters.

John T. Sacha joins R. P. Adams Co., Inc. as sales engineer to headquarter at the company's home office in Buffalo.

Richard S. Brent appointed district sales engineer in Chicago office of J. F. Pritchard and Co.

V. R. Farlow and **Robert L. Grun** to assist in sales and marketing development in expanding activities of Chemical dept. of Gulf Oil Corp.

L. L. Jaquier, Jr. and **Robert S. McConnell** take over positions in fertilizer sales div. offices of Phillips Petroleum Co., located at Bartlesville, Okla.

Edward Valves, Inc. appoints **Earl N. Stone** sales engineer in Middle West with headquarters in Denver, Colo.

The Chemstrand Corp. promotes **John C. Fisher** to staff purchasing agent.

Dow Chemical Co. consolidates organic chemicals sales section and fine chemicals sales unit under management of **James W. Harris.** Harris had been head of organic chemical sales. **Donald B. Black** takes over as manager of fine chemicals sales unit under new system.

Clay R. Brahm joins sales staff of Pennsylvania Salt Manufacturing Co.'s Metal Processing Chemicals Dept.

Seymour G. Linsley, formerly sales manager of laboratory instruments of The Perkin-Elmer Corp., named sales manager of Infrared Div. of Barnes Engineering Company, Conn. Linsley will have responsibility for sales of process control instrumentation and other products and auxiliary equipment for infrared components and systems.

people

J. H. Hayner joins Anaconda Co. to advise and assist company's interest in nuclear energy and to evaluate industrial utilization. Hayner will headquarter in New York.

Chester M. Brown named president of the General Chemical Div., Allied Chemical & Dye Corp. Brown has served with the company since 1929, and became executive vice-president of the division for which he is now president.

Necrology

Sydney Nashner, 43, general manager, Chemical Metallurgical Division, Sherritt-Gordon Mines Ltd., Fort Saskatchewan, Can.

Nashner, a member of the Institute since 1948, earned his bachelor's and master's degree at MIT.

Benjamin B. Freud, 73, emeritus professor and first chairman of the chemistry department, Illinois Institute of Technology.

A native Chicagoan, Freud received his bachelor's and doctor's degrees from the Univ. of Chicago, was a member of the faculty at Illinois Tech for 45 years.

James B. Montgomery, 42, research supervisor, Hercules Powder Co. Experiment Station, Wilmington, Del.

John M. Herndon, 48, director of manufacturing, Organic Chemicals Dept., Du Pont, Wilmington, Del.

Herndon, who joined Du Pont in 1933, earned his master's and doctorate at Penn State.

John J. Toe, 23, development engineer, Pittsburgh Coke & Chemical Co., Pa.

Fred W. Colucci, 53, asst. chief, industrial engineering, Wigton Abbott Corp., Newark, N. J.

Ralph R. Wenner, 50, Monsanto Chemical Co., Dayton, O.

Wenner, a member of the Institute since 1947, earned his bachelor's degree at Cooper Union, master's at Northwestern, and doctorate at California Institute of Technology.

Charles F. Duchacek, 38, senior chemical engineer, Technical Service Dept., Socony Vacuum Laboratories, Brooklyn, N. Y.

A.I.Ch.E. **News of the Field** FROM LOCAL SECTIONS

IMPROVING INDUSTRIAL COMMUNICATIONS

Lively panel session at Western New York Section meeting digs into the "what," "why," and "how-to" of improving industrial relations, emphasizes chemical engineer's role.

With panelists F. L. Bryant, Hooker, A. R. Mulligan, Bell Aircraft, E. J. Hasselbeck, National Aniline, and C. Vincent-Daviss, Du Pont, leading the way, Tom Hooker, Hooker Electrochemical, moderated the pros and cons of how to communicate in industry, both upwards and downwards.

L. to r., Hasselbeck, Mulligan, Hooker, Bryant, and Vincent-Daviss.

There was a time when the prevailing attitude in industry was "Never mind about why to do it, just do it!" But those days are gone, Bryant emphasized, and that's all to the good—men work better when they know why they are working. In Bryant's view the whole solution to the problem of industrial communications can be summed up in one word—More! More information on more things to more people more quickly.

In essence the engineer can be considered the "middleman" of industrial communications. Too often the men at the top fail to see all the good that can come from proper communications, and too often the worker feels exactly the same, with a certain amount of suspicion of management thrown in. The engineer is in the unique position of working closely with both management and the workers, he has reason to communicate with both. Perhaps his major communications job is to foster a proper attitude toward, and appreciation of, good communications.

Mulligan introduced the subject of the methods of communication. In actuality there are two methods of communicating, each with its two sides: speaking and listening, writing and reading. Today there seems to be a tendency to underrate speaking as a method of

A.I.Ch.E. — **News of the Field** FROM LOCAL SECTIONS

communicating in industry, but everyone knows that five minutes conversation with the "boss" is worth twenty memos or directives. When you speak to a man you can see his reaction, you can get his side of it at once.

The obverse of speaking is listening. Good speakers are rare but good listeners are even more rare. Listening is not easy, is not a passive matter. Listening, really listening, is hard work, but it is a vital part of good communications.

Perhaps the major lesson management must face is that communications are a two-way road. The engineer and the executive must be ready to listen as well as speak, read as well as write. The worker has something to say too. Good industrial communications cannot come from a one-way flow of words and ideas. To inform the worker is a step forward but it is only half the job. To Mulligan this was a particularly important point.

Turning to specifics, Hasselbeck showed the method of Staff Meetings used by National Aniline. In regular monthly meetings the company's department heads discuss, report, and analyze the company's methods, goals, trends, etc., with all the salaried personnel. The salaried personnel in turn are expected to carry on the communication down to the wage-workers.

It was left to Vincent-Daviss to bring out one of the most common reasons for bad communications, a reason everyone knows but few talk about—personal security, or fear, or self-interest, whatever you wish to call it. Communications to be valuable must be honest, open, and in a sense, selfless. Too often men hold-up communications for personal interest, by taking credit that isn't theirs, by a fear of having too many people know exactly what they are doing, by actually using the channels for personal advantage such as belittling other members of the firm.

In the discussion session from the floor the question was raised as to what the engineer can do if his "boss" just refuses to communicate properly? Consensus of the panel was that either the engineer must develop sort of a sixth sense to apprehend the bosses wishes, or take the bull by the horns and ask the boss a direct question to find out what he wants to know.

Good communications require a certain amount of "neck-sticking-out," and the engineer must learn to take the risk, it will pay in the long run.

News of the Field
FROM LOCAL SECTIONS

Baton Rouge, La. Automation can provide a great service to management by making it possible to have instantaneous knowledge of what is taking place in a process. But will it pay off? The answer, according to A. F. Sperry, president of Panelit Co., speaking at the Oct. 17 meeting of the Baton Rouge Section, lies in the area of increased efficiencies and product yields, as far as the chemical and petroleum industries go, and not in labor reduction.

—K. A. Rees

Providence, R. I. In its efforts to bring more industry to the Union's smallest state, the Rhode Island Development Council has established several new industrial parks, the largest of which is a 2,000-acre area along the main line of the New Haven R.R. in South County, which offers particularly good possibilities for the establishment of chemical industries.

Speaking to the November 17 meeting of the Rhode Island Section, T. A. Monahan, executive director of the Council, presented an extremely informative talk to the Rhode Island engineers on this subject of vital interest to all.

—A. R. Thompson

Denver, Colo. We are approaching the economic limit of increasing the compression ratio in the Otto cycle engine, new drilling techniques are getting us down farther and farther after oil, and new fuels, new engines, are challenging petroleum researchers. These were three of the major points of H. Gerchinowitz, president of Shell Development Co., in his talk to the November meeting of the Rocky Mountain Section.

Increasing compression ratio further in the Otto cycle engine means octane numbers over 100, and this means much higher costs which will probably prove uneconomic.

Even with such innovations as the turbine drill motor operating at the bottom of the shaft, a commercial development, incidentally, of the Russians, which will enable us to go much deeper than before, we are more likely to turn to turbine engines where fuel requirements are much less stringent.

Asked to rank the secondary fuel sources in order of economic importance, Gerchinowitz said: tar sands, heavy oil deposits, shale, coal hydrogenation. This is primarily for mobile power fuels, for stationary, large-scale power sources, atomic reactors are of great importance.

—R. M. Berry

CLASSIFIED SECTION

Address Replies to Box Number Care of CHEMICAL ENGINEERING PROGRESS

SITUATIONS OPEN

SOUTHWEST RESEARCH INSTITUTE

CHEMICAL ENGINEERS

Our services are expanding in the fields of industrial chemistry and petro-chemicals, process development and design, and fundamental chemical engineering studies. Opportunities to participate in challenging and constructive programs await chemical engineers, preferably with five years or more experience. We would like contact with qualified persons who would be interested in high level professional association in a growing region and under pleasant living conditions. All inquiries handled on a personal basis and treated confidentially.

Send résumé to: **Chemistry & Chemical Engineering Department**
SOUTHWEST RESEARCH INSTITUTE
San Antonio 6, Texas

Research work in the field of pulp, paper, and paper containers. Opportunity to do work on interesting industry problems in a stimulating academic atmosphere. Interested in adding several young men with background either in chemistry, physics, chemical or mechanical engineering.

The Institute of Paper Chemistry
Appleton, Wisconsin

CHEMICAL ENGINEERS

Several positions open at various levels of responsibility for men with BS or MS degree and 0 to 10 years' experience, preferably in organic chemical field. Openings are in process development, process design, and economic evaluation. Salary commensurate with experience and position in the organization.

If you qualify, and are looking for a future with a medium-sized progressive company, write giving résumé of experience, personal data, references, and salary requirements.

Pittsburgh Coke & Chemical Company
Neville Island
Pittsburgh 25, Pennsylvania
Attention: Mr. T. J. Junker

Development and Application Engineers

Major multi-plant chemical company needs several young chemical engineers, age to 35, who are interested in working in broadly diversified areas of engineering development and application. Principal duties include aiding plant operating, technical, and research personnel in problems requiring technical foresight and know-how for solution. Salaries attractive. Rate of advancement dependent only on engineer's own performance, demonstrated ability, and productive ambition.

Please submit detailed résumé, IN COMPLETE CONFIDENCE to:

Box 1-1

CHEMICAL ENGINEERS and CHEMISTS
Our New
MOLECULAR SIEVE ADSORBENTS
Offer
EXCELLENT OPPORTUNITIES
in
PRODUCT and APPLICATION DEVELOPMENT

Unusual career openings in the fields of adsorption, ion exchange and catalysis. Test marketing and customer liaison involved. Men with potential in technical sales may qualify later for responsible field positions. Industrial experience desirable but not mandatory.

- Bachelors or Masters Graduates
- Send résumé of educational background (include approximate academic standing) and work experience to:

LINDE AIR PRODUCTS COMPANY
a Division of
Union Carbide and Carbon Corporation
P. O. Box 44
Tonawanda, New York
Attention: Mr. Paul I. Emch
Refer to Ad: CEP MS

Chemical Engineers for Product and Process Development

Permanent staff positions are available for development of new catalysts, chemicals and catalytic processes for the petroleum and chemical industries. Work includes economic studies, pilot plant operation and commercial unit follow-up.

Experience is desirable, but initiative and ability are of most importance.

Send details of experience, education, and salary requirements. Prompt consideration and complete privacy is assured. Address applications to:

HOUDRY
Process Corporation
BOX 427
MARCUS HOOK, PA.

CHEMICAL ENGINEERS

For pilot plant and process development work. All degree levels, recent graduates or up to five years' experience.

Expanded program of process development, process improvement and pilot plant production in connection with commercialization of new Phillips developed petrochemicals has created several openings for young engineers. Development engineers are also needed for other chemical and petroleum projects.

ENGINEERS, MATHEMATICIANS AND NUMERICAL ANALYSIS

For programming magnetic drum computer for the solution of chemical and petroleum process design, operations research, atomic energy, and rocket fuels problems. Magnetic drum computer and data communication facilities now being integrated into a large central computing facility. A staff with varied background is to be further developed.

Located in modern, medium-sized Southwestern community. Excellent company recreation facilities, retirement, insurance and thrift programs.

Please submit brief résumé to:

Employee Relations Manager
Research and Development Department
Phillips Petroleum Company
Bartlesville, Oklahoma

SENIOR ENGINEER

Metallurgical Research

For Materials Research and Radiation Studies Group of the Aircraft Nuclear Propulsion Department.

A senior research position is now open in an advanced project . . . the application of nuclear energy to the field of flight. The engineer who qualifies will be responsible for research designed to provide improved metals and alloys for use in an aircraft nuclear power plant.

The job requires **a degree** in physical metallurgy or **metallurgical engineering** and 8 to 10 **years experience** in working with high **temperature** or corrosion resistant **metals and alloys**. (If directly related, time spent on obtaining an advanced degree may be considered part of this experience.)

Publication of Research Results in the Appropriate Classified or Open Literature is Encouraged.

Positions Open in Cincinnati, Ohio and Idaho Falls, Idaho

Send complete résumé to:

MR. W. J. KELLY, G. E. CO.
P. O. Box 132, Cincinnati 15, Ohio

MR. L. A. MUNTHER, G. E. CO.
P. O. Box 535, Idaho Falls, Idaho

GENERAL ELECTRIC

- Union Carbide's
- New Division
- Offers New
- Opportunities

UCC

CHEMICAL ENGINEERS AND PHYSICISTS

Experienced in Nuclear Engineering

- For development and design of chemical processes to handle nuclear fuel materials for all types of
  Heterogeneous reactors
  Homogeneous reactors
- For design of radiochemicals separations and applications research facilities.

LOCATION—NEW YORK CITY

Send your résumé to

PERSONNEL DEPARTMENT

UNION CARBIDE NUCLEAR COMPANY

A Division of Union Carbide and Carbon Corporation

30 East 42nd Street
New York 17, New York

WANT TO LIVE IN SUNNY TUCSON? CHEMICAL ENGINEERS, production experience in pulp or paper manufacture, for technical studies and sales engineering with large established manufacturer of water and waste treating equipment. Work in famous health and recreation area; ideal dry Southwestern climate. Write box 6-1.

CHEMICAL PLANT AND EQUIPMENT ENGINEER

National paint manufacturer offers excellent opportunity for graduate chemical engineer with mechanical background. Paint industry background preferred but will consider allied industrial chemical experience. Position is largely of advisory capacity. Mechanical requirements involve application equipment engineering and layout of buildings, equipment, pipelines, electrical services, heating, and ventilating. Salary open. Reply with educational and employment qualifications.

THE GLIDDEN COMPANY

R. G. McKay, Personnel Department
11001 Madison Avenue
Cleveland 2, Ohio

DEVELOPMENT ENGINEERS

Expanding process development group of research department needs several young chemical engineers, 0 to 4 years' experience. Chiefly for pilot plant work involving some shift operation. Location Westchester county. Residential suburb near New York City. These positions present excellent opportunities for advancement with one of the chemical industry's leading growth companies. Very interesting assignments, responsible work with limited supervision. Reply stating salary requirements, include recent photo if available.

Box 4-1

UNUSUAL CAREER IN *SALES APPLICATION RESEARCH*

Large progressive eastern chemical company has openings for two graduates under 35 with technical degrees for applications research on transparent flexible films. Will also consider younger men who are interested in growing in this most interesting field.

Experience in laminating is desirable but not essential.

Duties will include study of applications of all types flexible films in customers' and potential customers' products and processes. Both laboratory investigations and cooperative technical work with customers are involved. Replies held confidential. Please send complete résumé including salary expected and details of education and experience. Our employees know of this ad.

Box 3-1

CHEMICAL ENGINEERS AND CHEMISTS

Plant development and research on cellophane. Excellent opportunities for advancement. Salary open, depending on experience. Submit résumé and photograph. Box 5-1.

DIRECTIONS FOR USE OF CLASSIFIED SECTION

Advertisements in the Classified Section of Chemical Engineering Progress are payable in advance at 20¢ a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed one six-line Situation Wanted insertion (about 36 words) free of charge a year. Members may enter more than one insertion at half rates. Prospective employers and employees in using the Classified Section of Chemical Engineering Progress agree that all communications will be acknowledged; the service is made available on that condition. Boxed advertisements are available at $17 a column inch. Size of type may be specified by advertiser. Answers to advertisements should be addressed to the box number, Classified Section, Chemical Engineering Progress, 25 West 45th Street, New York 36, N. Y. Telephone COlumbus 5-7330. Advertisements for this section should be in the editorial offices the 15th of the month preceding publication.

A.I.Ch.E.

News of the Field

FROM LOCAL SECTIONS

Boston, Mass. Over 1000 people all working solely on research, development and engineering for the comfort and well-being of the foot soldier, is a description of the new Army Quartermaster Research and Development Center at Natick, Mass., visited in November by the members of the Boston Section. Impressed Boston engineers named the Center "one of the most magnificent scientific establishments in the country."

—A. S. Collins

Pittsburgh, Pa. The operation of any nuclear reactor produces much radiation which may be used if the problems and economics associated with radiation processing can be solved.

Speaking at the December 7 meeting of the Pittsburgh Section, J. J. Martin, Univ. of Michigan, told of Michigan's efforts to find economic uses for radiation, particularly that available from fission products. At present, triggering or catalyzing chemical reactions shows the greatest promise, chain reactions with a negative free energy charge getting most attention.

—J. R. West

Louisville, Ky. Introduction of natural gas into an area opens a multitude of opportunities for the chemical manufacturer. But the economic aspects of producing the various end-products of natural gas-based operations will vary considerably, according to the proximity of potential markets, availability of alternate starting materials, cost of required intermediates, utilities, and the natural gas itself.

With this basic presentation, N. C. Updegraff, Gas Process Division of Girdler, discussed basic chemicals from natural gas at the October meeting of the Louisville Section.

Continuing on a presentation of the "reforming" process, which is the reaction of hydrocarbons with steam and/or oxygen to produce a mixture of hydrogen and carbon oxides, Updegraff pointed out that the process was only one in which natural gas can be utilized, in this case it produces either hydrogen, carbon monoxide, a ratio of both, or, if nitrogen is added, ammonia, carbon dioxide and, by reacting CO_2 with ammonia, urea.

Other processes are: The production of hydrogen cyanide by reaction of ammonia, natural gas and air over a platinum catalyst, and the two processes for the production of acetylene, the Sachsse, and the Wulff.

—F. G. Smith, Jr.

SITUATIONS WANTED

A.I.Ch.E. Members

PRODUCTION ENGINEER—M.Ch.E. Age 38. Recognized fourteen year record of accomplishments in plant and process engineering, trouble-shooting, assistant to vice-president charge of production, chief engineer for multi-plant organization, plant manager of fermentation alcohol plant. Seeking responsible position in production, engineering or management. Box 7-1.

TECHNICAL SUPERVISOR—M.S. Age 42. Nineteen years' experience in petroleum and petrochemicals. Research, pilot plant, and process engineering in industrial plant. Any location considered, but prefer Southwest. Box 8-1.

SENIOR CHEMICAL ENGINEER—B.S. in Ch.E. Age 33, eight years' experience in process design, and commercial plant operation. Process design in chemical, petroleum, metallurgical, and A.E.C. fields. Plant operation in petroleum refining. Desire supervisory position with a petroleum or chemical company. Box 9-1.

CHEMICAL ENGINEER—B.Ch.E., 1950. French Doctorate (University of Paris) expected date February 1956. Age 27, veteran, publications, fluent French. Three years' diversified experience mainly in research and development. Available for interview New York area March 1956. Box 10-1.

CHEMICAL ENGINEER — PHYSICIST — B.S. Ch.E., 1942; M.S. Physics, 1949; course work for doctorate in physics. Fourteen years' progressive experience: gas and organic analysis, pilot plant, engineering design, teaching, electronics, physical research, and at present supervision of aerosol and aerodynamic research. Desires responsible position R & D with future. Age 38, family. Box 11-1.

MANAGEMENT ENGINEER—Project organization, coordination, liaison, control; preliminary and budget estimating; planning and scheduling. Management-thinking, cost-conscious, technically competent individual desires responsible staff position. Age 34, B.S.Ch.E. Box 12-1.

CHEMICAL ENGINEER—Ph.D., P.E., age 29. Three years' industrial research and process development; three years' teaching experience. Seeks challenging opportunity with promising future in industry or teaching. Prefer New York, New Jersey, Connecticut area, but others considered. Married, family, veteran. Box 13-1.

ECONOMIC EVALUATION—cost estimation, process engineering in the petrochemical, fertilizer, and organic field for 2½ years—three years' other engineering experience. Chemical engineer, age 31, family, veteran. B.S.Ch.E. with honors, graduate work, etc. Minimum salary, $7,500. Box 14-1.

CHEMICAL ENGINEER—Age 35, Ph.D., married. Experienced in pilot plant supervision, process engineering, and process coordination in synthesis organics, vitamins, antibiotics, steroids, and organic acids. Ability at organization and cost analysis. Desires executive position with small company. Box 15-1.

CHEMICAL ENGINEER—Age 29, veteran. Five years' experience foreign trade, one year test engineer. Fluent French, German and Spanish. Desires challenging position marketing, sales or management. B.S.Ch.E. 1955. Location immaterial. Foreign assignment considered. Box 16-1.

Nonmember

ENGINEER.—Age 38, experienced plant electrical engineering large chemical and industrial plants, including power generation, distribution, short circuit calculations, motor application, controls, electrical and electronic maintenance. Some experience general plant engineering and plant utilities. Prefer eastern United States. Box 17-1.

A.I.Ch.E.

News of the Field

FROM LOCAL SECTIONS

Akron, O. First 1 billion pound per year plastic will be polyethylene, predicted R. B. Seymour, Loven Chemical Corp. of California, at the November meeting of the Akron Section.

Emphasizing the application of plastics to corrosion problems, Seymour cautioned against the use of plastics where there is no distinct advantage to be gained in operation.

—T. H. Rogers

Tulsa, Okla. The basic relationships of thermodynamics are invaluable aids in evaluating the efficiency of a chemical process. This was the essence of the latter part of C. M. Sliepcevich's, new chairman of the School of Chemical Engineering at the Univ. of Oklahoma, talk to the October meeting of the Tulsa Section. Sliepcevich began his talk with a review of the developments at the School of Engineering.

—J. H. Kelly

East Tennessee. Clarification of liquids by filtration is a controversial subject since it has never reached the stage of a mathematical science, it is still necessary to perform actual pilot plant filtrations to determine filtration characteristics in any specific case.

R. W. Hess, Duriron Co., explained this fact to the November meeting of the East Tennessee Section, went on to define clarification of liquids by filtration as an operation where the liquid is the desired end product, and the solids are less than 3% by weight.

In this type of work filter aids are nearly always necessary, particularly when using pressure leaf filters.

—P. C. Underwood

Rochester, N. Y. The mingling of scientists is bound to promote international understanding, pointed out W. G. Whitman, M.I.T., president-elect of A.I.Ch.E., in a talk before the Rochester Section in November.

From his experience as Secretary-General of the International Conference on Atomic Energy at Geneva recently, Whitman has learned the value of working with other nations, emphasized the strong participation and cooperation of the Russians at Geneva.

A major point brought out by the Geneva meeting was that the production of nuclear energy is now mostly a problem of economics since the world's supply of fissionable ore has been found to be adequate.

—J. E. Millard

INDEX OF ADVERTISERS

C.E.P. Advertising Offices

New York 36—Lansing T. Dupree, Adv. Mgr.; John M. Goede, Asst. Adv. Mgr.; Paul A. Jolcuvar, Dist. Mgr.; Donald J. Stroop, Dist. Mgr.; 25 W. 45th St., Columbus 5-7330.

Chicago 11—Richard R. Quinn, Dist. Mgr., 612 North Michigan Ave., Room 507, Superior 7-0385.

Cleveland 15—Eugene B. Pritchard, Dist. Mgr., 1836 Euclid Ave., Superior 1-3315.

Pasadena 1—Richard P. McKey, Dist. Mgr., 465 East Union St., Ryan 1-8779.

news and notes

A.I.Ch.E.

New Engineering Center: B. F. Dodge, Chairman of the Special Task Committee for the Engineering Center, reported recently to each society that the firm of McKinsey & Company, management consultants, has been retained to help the Task Committee select a site for the engineering center . . . The magnitude of the task is such that the group has asked for an extension of time from that originally specified, February 1, 1956, to May 1, 1956 . . .

Nuclear Engineering Division of the A.I.Ch.E. has had an eventful year under the chairmanship of R. P. Genereaux . . . Recent elections provide that for 1956 the new chairman will be Miles C. Leverett, vice-chairman will be Herbert S. Isbin, J. J. Martin continues as secretary-treasurer, & James A. Lane has been elected the new member of the Executive Committee.

Chicago Section recently established an award to honor Harry McCormick, a past chairman & charter member of the Chicago section, a well-known teacher of chemical engineering, & a long-time member of the A.I.Ch.E. . . . The award is to be given to the top student in chemical engineering at Illinois Institute of Technology & at Northwestern Technological Institute . . . Award is based on scholarship, activities, & potentialities.

Canadian Meeting is planned for April 20-23, 1958, in Montreal, Canada, with the Chemical Institute of Canada . . . A meeting is also tentatively scheduled to be held in Mexico some time in 1960 if conditions permit.

Two New Local Sections were authorized, the Alton-Wood River Section & the Coastal Bend Section, which has headquarters in Corpus Christi, Texas.

Fiftieth Anniversary Committee was organized by Council to be composed of former presidents of A.I.Ch.E. with C. G. Kirkbride as chairman . . . The History of the Institute Committee becomes a subcommittee of the Anniversary Committee . . . The new Anniversary group will plan the organization of the Fiftieth Anniversary Meeting, which will be held in Philadelphia, June 22-28, 1958.

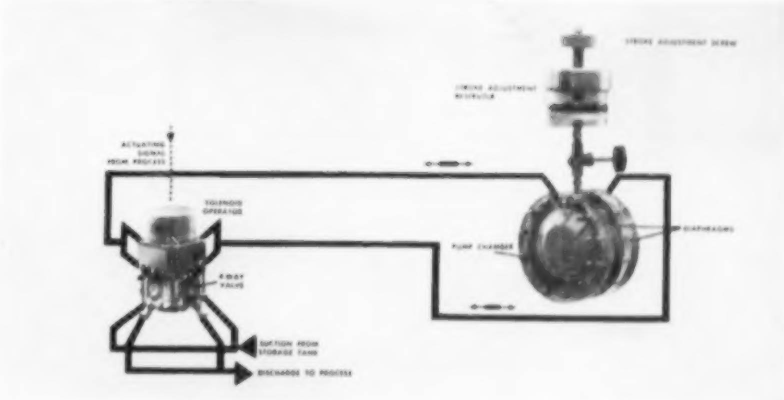
Much Was Accomplished at the Annual Meeting in November . . . A long line of impressive reports from chairmen of committees was heard, and the progress of the Institute through these functioning bodies was heartening to learn . . . Through the year we will try to brief you on some of the activities that have been reported in the hopes that you, as members, on reading of some undertaking in which you are particularly interested will be encouraged to volunteer your assistance to the chairman.

F.J.V.A.

NOW! Downhill metering!

The new Milton Roy −ΔP PUMP

In operation, the four-way valve admits fluid to one side of the pump chamber, forcing a slack diaphragm to displace fluid from the opposite pump chamber. This procedure reverses on the next cycle. The pacing valve can be operated manually, mechanically, electrically, or pneumatically.



FEATURES

- Leakproof
- No stuffing box
- No running seal
- No contamination
- No lubrication
- Accuracy within plus or minus 1%
- Easily dismantled

LITERATURE

For complete details write today for *Bulletin 955!* Milton Roy Company, *Manufacturing Engineers*, 1300 East Mermaid Lane, Philadelphia 18, Pa.

TELL US YOUR PROBLEM

Milton Roy engineers will gladly analyze your operation and advise you of the ways "downhill metering" might be applied in solving your particular pumping problem. Write us today.

Downhill metering (controlled volume pumping from higher to lower pressures) is now practical. The −Δ**P** pump uses a new concept in controlled volume pumping to meter clear fluids (liquids or gases) wherever suction pressure is at least 5 psi greater than discharge pressure.

External power sources are often unnecessary since the −Δ**P** pump can use the potential energy of the fluid (stored either under pressure or in an elevated location). The basic leakproof diaphragm design (for both meter and pacing valve) and a wide selection of materials of construction make the −Δ**P** pump particularly adaptable to handle corrosive or hazardous fluids. For specification data, write for Bulletin 955 . . . to Milton Roy Co., 1300 E. Mermaid Lane, Phila. 18, Pa.

Engineering representatives in the United States, Canada, Mexico, Europe, Asia, South America, and Africa.

milton Roy

CHEMICAL FEED SYSTEMS